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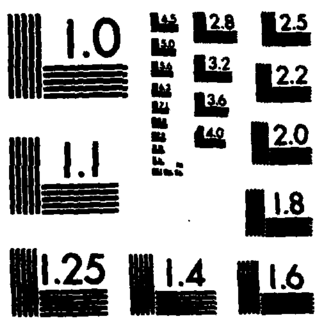

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A major premise of DOD incentive contracting for the development and production of new weapon systems is that contractors are primarily motivated to maximize profits. Research, however, suggests that the goal structure of contractors consists of survival, growth, market share, and reputation as well as profit. The relative operational importance of these goals is significantly influenced by the positions and responsibilities of the contractor's primary decision makers.

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20. Past research has failed to understand the differences between the traditional and the defense contracting markets. In this research, a computer simulation called the Decision Process Model (DPM) is developed which describes the organizational and contractual interaction of the defense contracting firm with the DOD by focusing on the decision process at the project manager level. The DPM simulates the actions of a project manager in a defense contracting firm and the interdependent actions of corporate and DOD management in a dynamic framework. It models actions on three organizational levels: contractor project manager, corporate level manager, and Government project manager. Basic elements incorporated into the model are DOD project goals, DOD incentive mechanisms, contractor goals, and contractor organizational response mechanisms. Each element is decoupled and parameterized to facilitate analysis of different incentive schemes and behavioral assumptions. Future research on the DPM will include validation studies consisting of scenario analysis, sensitivity analysis, and external validation.

DECISION PROCESS MODELS OF CONTRACTOR BEHAVIOR:

The Development of Effective Contract Incentives

Multi-Project Decision Process Model

Final Technical Report

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EXECUTIVE SUMMARY*

INTRODUCTION

A Major premise of incentive contracts as applied by the DOD in the development and procurement of new weapon systems has been that defense contracting firms are primarily motivated to maximize profits ~~[4].~~ Research, however, suggests that the goal structure of contractors consists of survival, growth, market share, and reputation as well as profit ~~[e.g. 1,9,10,11].~~ Furthermore, the relative operational importance of these goals is observed to be significantly influenced by the positions and responsibilities of the relevant decision makers within the contracting organization ~~[6,7].~~

Generally speaking, survival is perceived by contractor management to depend on attaining project performance objectives which affect company reputation and the ability to obtain future business [5]. Maintaining quality technical and administrative personnel, even in the face of declining business activity, is also thought to be critical to securing future large-scale contracts [8,12]. Growth in market share is pursued as a means to improve internal capabilities, develop barriers to entry by potential competitors, and as a means to spread fixed costs over a larger base. In short, contractor management (at various levels) is observed to voluntarily sacrifice short-run profits on a given DOD contract in favor of:

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*A variation of this Executive Summary is forthcoming as Daniel L. Blakley, Kalman J. Cohen, Arie Y. Lewin and Richard C. Morey, "Determinants of Defense Contractor Performance: a Decision Process Simulation Modeling Approach", Simulation.

i) improving opportunities for future follow-on projects,

ii) promoting technology spin-offs to commercial businesses,

iii) acquiring or maintaining quality personnel in scarce disciplines, and/or

iv) gaining competitive advantage by engaging in research instrumental to future product development.

We view the typical prime defense contracting firm as having a DOD business as well as an organizationally distinct commercial business (see Exhibit 1). The defense business, managed by a project manager (PM), consists of a number of projects awarded by the DOD. Likewise, the commercial business consists of a number of product lines, some of which benefit from technology developed under DOD contracts [6]. In addition, indirect costs of the commercial sector may potentially be transferred to DOD projects due to the establishment of a larger overhead base [8].

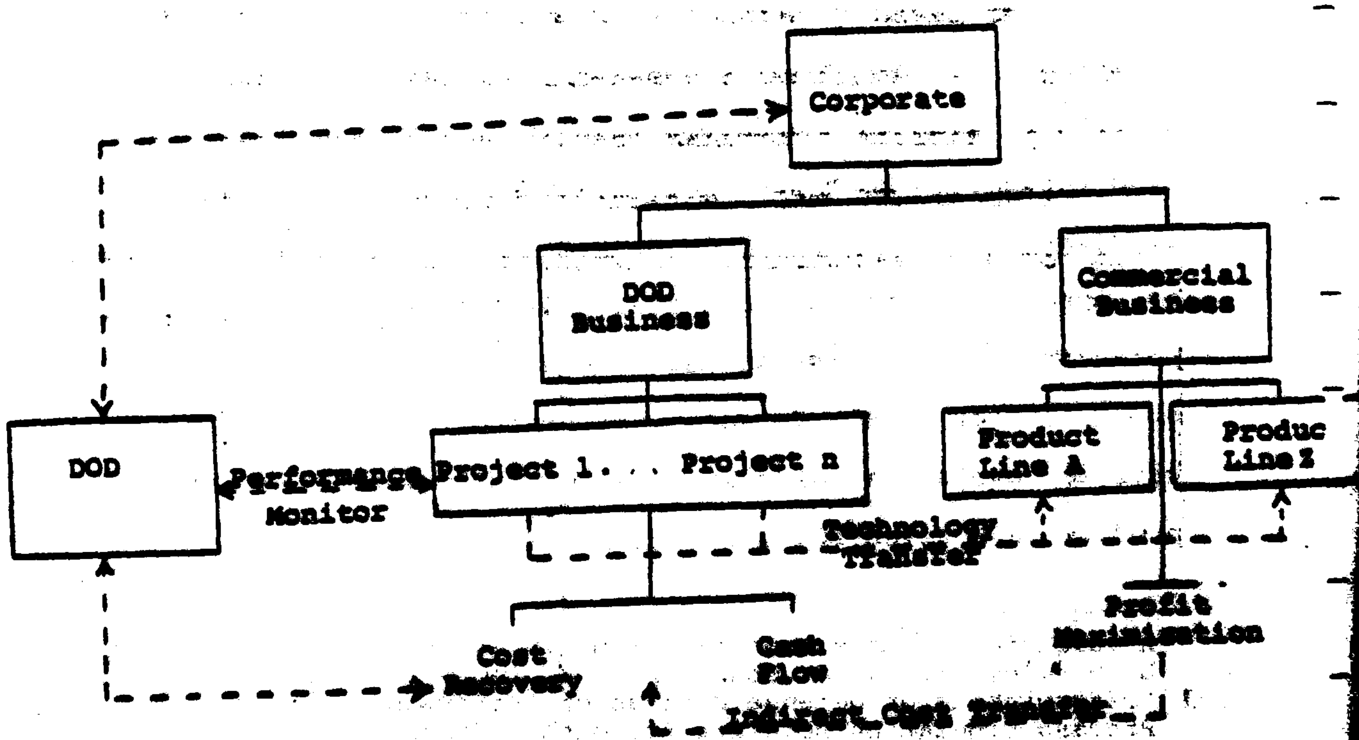


Exhibit 1

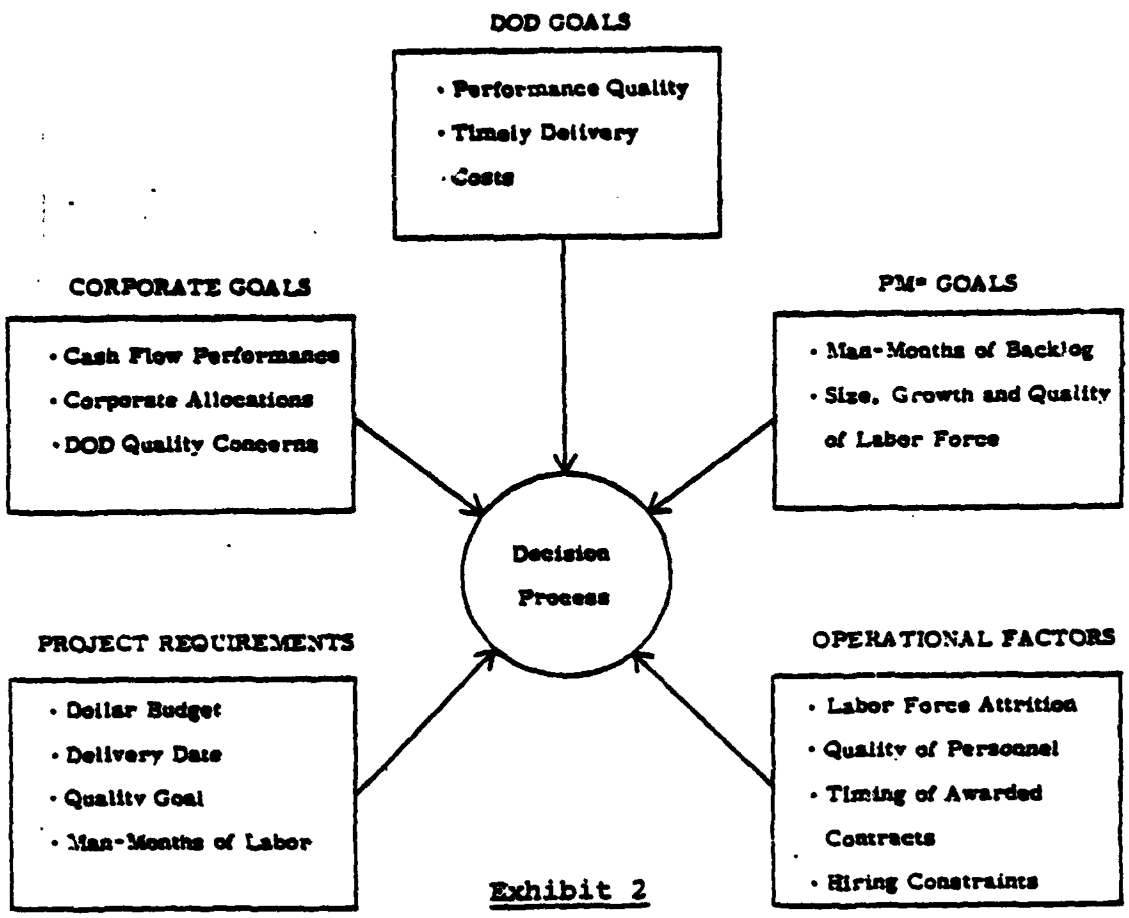
While the commercial sector of the firm may be based on profit maximizing considerations, the DOD business strategy focuses on achieving survival, growth, and prestige goals subject to maintaining a necessary level of cash flow. While a manager in the commercial market environment affects revenues by control of such variables as price, product attributes, production levels, inventory, etc., the manager of DOD projects has little operational control over standard economic decision variables as they are determined ex ante via contractual negotiations. Revenue is based on cost recovery; specifically on the recovery of direct and indirect costs billed against existing projects. A fundamental failure of past research has been the lack of a clear-cut understanding of the differences between doing business in the traditional market environment and the defense contracting environment described above.

This research project involves the development of a computer simulation model which describes the organizational and contractual interaction of the defense contracting firm with the DOD by focusing on the decision process at the project manager level--i.e., decisions which ultimately determine the performance of the contractor on a given project. An objective of this research is to develop a capability to model the potential impact of various incentive schemes on the performance of defense contracts. It is necessary, therefore, to incorporate in the simulation model such basic elements as DOD project goals, DOD incentive mechanisms, contractor goals, and contractor organizational response mechanisms. Each of these elements, which collectively determine the behavioral pattern of the decision process model (DPM), are decoupled and parameterized to facilitate analysis of different incentive schemes and/or behavioral assumptions.

SIMULATION ENVIRONMENT

The DPM consists of eight loosely coupled sub-models which operate on three organizational levels: the project manager level, the corporate level, and the DOD level. Each organizational level contains a separate set of goals, expectations, and decision processes which are simulated by the appropriate sub-models (discussed below). Various operational factors and project requirements are also important dimensions of the simulation environment. The synthesis of these goals and constraints into an operational plan by the project manager is the foundation of the DPM (see Exhibit 2).

The DPM is designed to simulate the actions of a project manager in a defense contracting firm and the interdependent actions of corporate and DOD management in a dynamic framework. Decisions of the project manager are made on a monthly basis, while corporate decisions are made quarterly based on the project manager's previous three-month performance. The DOD is also interested in the project manager's actions, but only as they influence project performance. The DOD is able to monitor specific project performance attributes on a monthly (but delayed) basis.



<u>Exhibit 2</u>

Contracts awarded by the DOD consist of heterogeneous projects with several distinguishing attributes. Each project is considered either a Major Project or a (significantly smaller) Spinoff Project with a dollar budget, delivery date, and an amount of standard quality of man-months (SQMMs) of work to be performed. In addition, Major Projects require that a specific quality standard be attained before the project is considered acceptable for delivery to the DOD.

A primary goal of the project manager is to control the backlog of awarded projects within maximum and minimum boundaries. The mechanism by which man-months of backlog may be influenced (besides the obvious effects of hiring and firing) involves the assignment of workers under the project manager's responsibility to indirect activities. By increasing the size of the indirect workforce, the project manager is able to increase the number of proposals submitted to the DOD. Likewise, by improving the quality of personnel writing proposals, the project manager is able to increase the capture rate of the resultant proposals. The quantity and quality of submitted proposals, in addition to performance on previous contracts, is assumed to determine the subsequent awarding of new projects by the DOD [14]. Thus, by increasing the size or quality of the indirect (proposal writing) workforce, the project manager is able to increase the number of awarded projects and, ceteris paribus, the man-months of backlog.

A secondary, but related, concern of the project manager involves the quality, size, and growth of technical staff. The workforce consists of high and low quality personnel which are assumed distinguishable to the project manager in the implementation of worker assignment and hiring/firing decisions. Limits exist, however, on the availability of high quality workers--although the project manager is able to hire low quality personnel as necessary to fulfill labor requirements.

Higher attrition rates, salary rates and marginal products are associated with high quality workers relative to low quality. In general, the DPM simulates the project manager pursuing, subject to various operational constraints and pressures (discussed below), the attainment of personal backlog and staffing goals by implementing specific workforce assignment and hiring/firing decisions on a monthly basis.

The corporate-level, on the other hand, is concerned with the cash flows, significant cost overruns and the resultant impact on the financial position of the firm. If the quarterly performance is unsatisfactory, pressure is applied on the project manager to increase cash flow. The project manager is able to improve cash flow by increasing the amount of billable time charged against existing contracts (i.e., increase the number of workers on direct activities) and/or decrease current cash expenses (i.e., implement firing decisions). An additional concern of corporate is the level of allocations in support of IR&D and administrative expenses levied on the project manager's organization.

Finally, the DOD monitors the performance of the project manager with respect to individual projects. Specifically, the DOD is concerned with: a) total costs as determined by cumulative billings against a contract; b) performance quality as reflected in the average quality of personnel used in satisfying the SQMM requirement; and c) the time period in which the product is available relative to the contracted delivery date. The exhaustion of the SQMM balance does not necessarily coincide with that of the dollar budget and, dependent on the contract-

type utilized, excess costs are not fully billable to the DOD. When quality or schedule problems are identified by the DOD, pressure is applied on the project manager. If project manager pressure does not result in improved performance, the DOD may convey its concerns to the corporate-level, dependent on the severity of the problem.

In summary, the interaction of the various organizational levels and their associated goals and expectations combined with the many operational factors and constraints faced by the project manager provide a realistic operating environment for the DPM. The DPM also demonstrates interesting dynamic properties in that project manager and corporate-level goals are modified throughout the simulation, dependent on prolonged success or failure. (DOD goals are assumed static and determined with the awarding of a contract.) Exhibit 3 illustrates the dynamic interaction of the project manager, corporate, and DOD organizational levels during the course of a simulation.

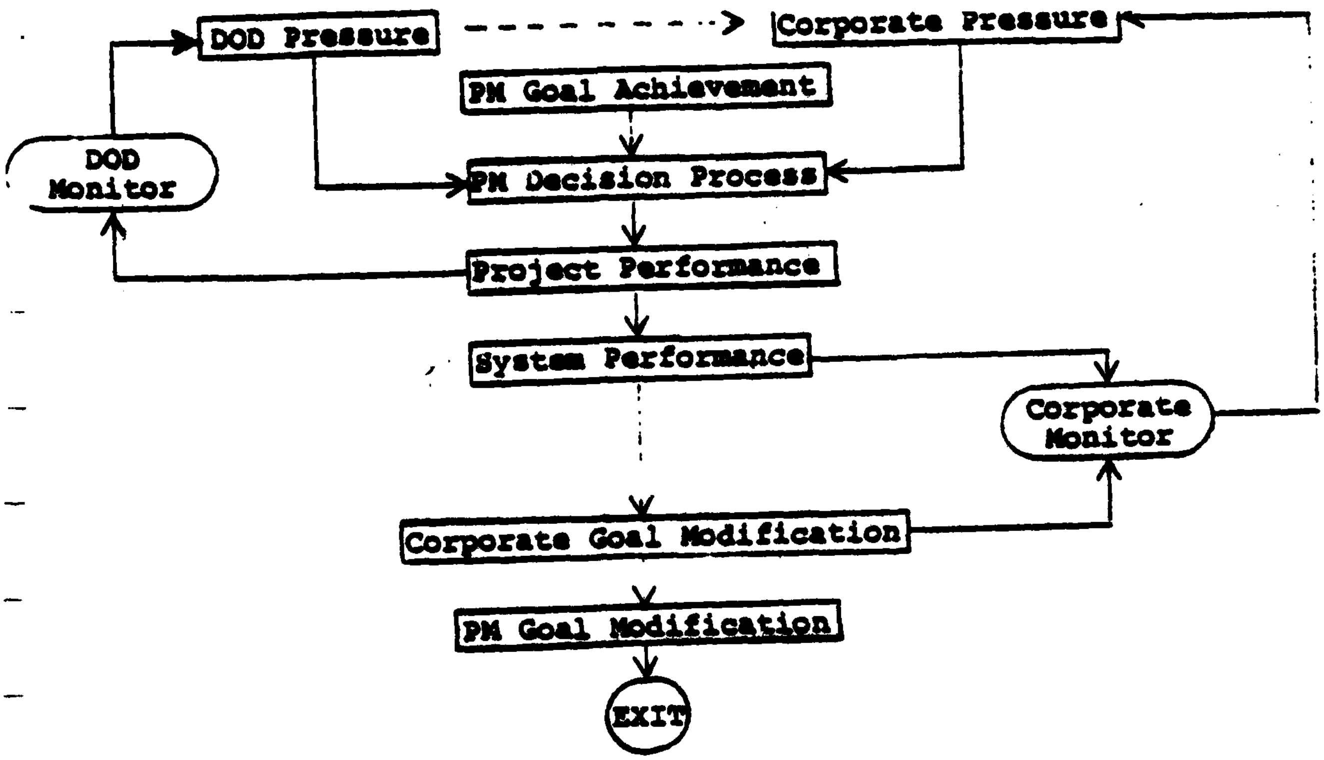


Exhibit 3

MODEL DECOMPOSITION

Exhibit 4 provides a listing and ranking of the various pressures and goals facing the project manager as they are currently incorporated into the DPM logic flow. The paramount concerns of the project manager involve Corporate Cash Flow Pressure, DOD Schedule Pressure, and/or Deficient Quality on

a completed project. The project manager is assumed to address these occurrences before considering remaining problems. Other pressures and unsatisfied goals are not ignored, but are given secondary consideration if they are in conflict with higher ranking priorities.

The next level of influence on project manager behavior concerns DOD quality pressure relayed from the corporate-level, Corporate Quality Pressure. The DOD, as mentioned above, approaches the corporate-level with quality concerns only if previous DOD Quality Pressure has been ineffective. As illustrated in Exhibit 4, this may occasionally occur as the Backlog Goal of the project manager takes precedence over DOD Quality Pressure. Finally, the Volume Goal of the project manager is the lowest ranking consideration in the attention hierarchy.

Level 1:	Corporate Cash Flow Pressure DOD Schedule Pressure Deficient Quality on Completed Project
Level 2:	Corporate Quality Pressure
Level 3:	Backlog Goal
Level 4:	DOD Quality Pressure
Level 5:	Volume (staff) Goal

<u>Exhibit 4</u>

PM Manpower Assignment Sub-Model

The purpose of the PM Manpower Assignment Sub-Model is to assign each high and low quality worker to indirect proposal development activities or to a specific project. As discussed above, the project manager is assumed to make personnel allocation decisions based on the existence of various DOD and corporate pressures, the achievement of personal goals and the individual constraints posed by the backlog of incomplete projects.

Project Update Sub-Model

Based on the personnel allocation decision made by the project manager with respect to the quantity and quality of work performed on each project, several running measures must be updated for each project worked on. Specifically, the remaining dollars in the budget and the required SQMM balance must be decreased and the quality index of work performed adjusted accordingly. Finally, the time remaining before each project is due is calculated.

Personnel Sub-Model

The objective of the Personnel Sub-Model is to implement the decisions made by the project manager with respect to alterations in the size of the workforce. Labor force attrition is also reckoned with in this sub-model and is assumed to occur simultaneously with the project manager's hiring/firing

decision--i.e., the project manager is unable to compensate for attrition in the current period. The output of the Personnel Sub-Model is a description of the end-of-the-period labor force in terms of size and quality composition.

Backlog Determination Sub-Model

Based on the output of the previous sub-models, the Backlog Determination Sub-Model calculates the number of months of backlog (given current staffing levels) at the end of the period. This involves determining whether a project has been awarded and, if so, the dollar, delivery date and SQMM size of the new project.

Cash Flow Determination Sub-Model

The Cash Flow Determination Sub-Model calculates the direct and indirect costs associated with the project manager's operation and the cumulative billings to the DOD allowed for the direct work performed on individual projects. Billings against a particular project are allowed only if the budget has not been depleted. Once the target cost on a given project has been reached, the contractually specified cost-sharing formula allocates subsequent cost-overruns between the contractor and the DOD. If the ceiling cost is exceeded, all further expenses incurred on a given project in satisfaction of SQMM requirements and/or quality standards are fully absorbed by the contractor.

Corporate Goal Adjustment Sub-Model

The output of the Corporate Goal Adjustment Sub-Model is a determination of the level of appropriations in support of corporate administrative and IR&D expenses that is levied on the project manager's operation. Also a decision as to whether to apply cash flow pressure on the project manager is reached.

PM Goal Adjustment Sub-Model

The PM Goal Adjustment Sub-Model is responsible for modifying the project manager's personal Backlog and Volume goals based on the success of past and current performances and the existence of pressures from the corporate and DOD levels.

DOD Sub-Model

The DOD Sub-Model monitors progress made on each of the projects awarded to the defense contractor and determines whether schedule and/or quality pressure should be applied at the project manager or corporate levels.

MODEL SOLUTION

All sub-models have several functional categories which collectively describe the work flow during the solution sequence. Each sub-model, except several routines in the Corporate Goal Adjustment Sub-Model (which are solved quarterly), are solved each time period of the simulation. A complete listing of the various sub-models and associated routines is provided in Appendix I.

As shown in Exhibit 5, the simulation begins with solution of the PM Manpower Assignment Sub-Model. This involves the project manager reviewing the operating environment (see Exhibit 3) taking note of various pressures and goal achievement. The labor force is then broken down between indirect and direct activities and assigned to specific tasks; either proposal writing or to an incomplete project. Decisions are also made concerning hiring or firing. After solution of the PM Manpower Assignment Sub-Model, each project in the project manager's backlog is updated through solution of the Project Update Sub-Model.

The Personnel Sub-Model is then solved which determines the size and quality composition of the labor force at the end of the period--taking into account the hiring and firing decisions of the project manager and labor force attrition. The Backlog Determination Sub-Model utilizes the output of the Personnel Sub-Model and calculates the actual months of backlog in the project manager's incomplete project inventory at the end of the period. This also requires determining if a new project has been awarded in the current period.

After solution of the Cash Flow Determination Sub-Model, the Corporate and Project Manager Goal Adjustment Sub-Models are solved. Finally, the DOD Sub-Model which monitors individual project performance, is solved.

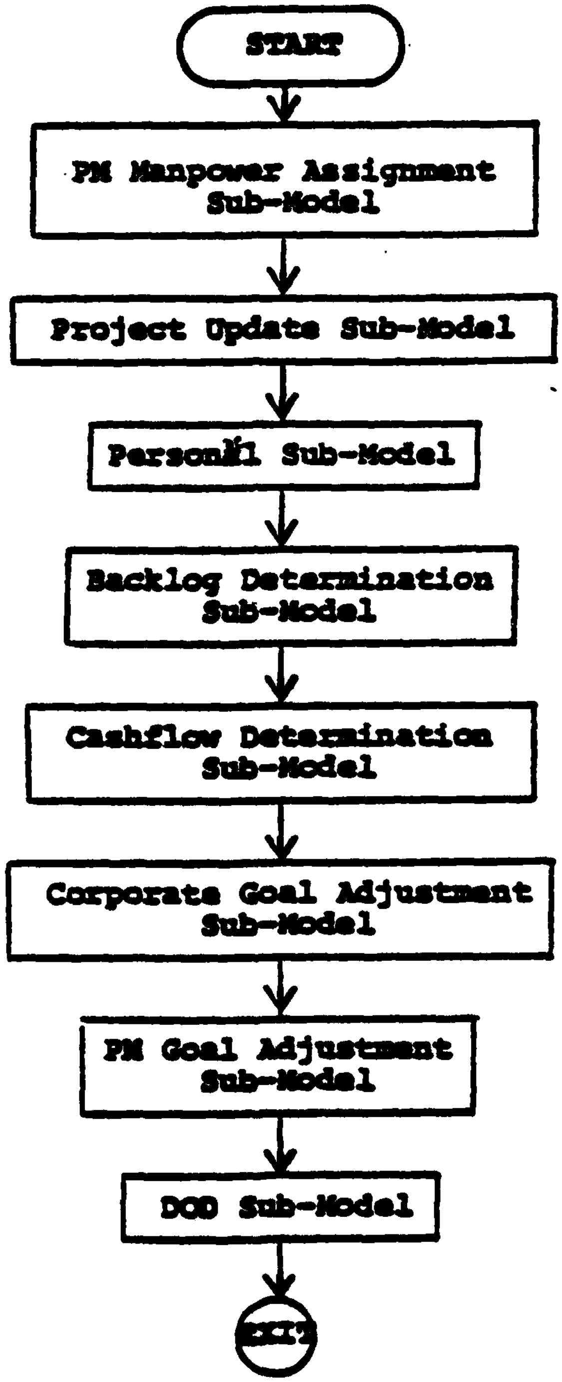

START
PM Manpower Assignment Sub-Model
Project Update Sub-Model
Personnel Sub-Model
Backlog Determination Sub-Model
Cashflow Determination Sub-Model
Corporate Goal Adjustment Sub-Model
PM Goal Adjustment Sub-Model
DOD Sub-Model
EXIT

Exhibit 5

VALIDATION AND APPLICATION

Despite progress made in simulating a sophisticated and realistic operating environment, the DPM's structural specification and behavioral parameters must necessarily be tested and validated before policy recommendations may be made. The first phase of model validation involved conducting field interviews with the DOD and defense contractor project managers. In addition to facilitating the initial model specification, field interviews allowed the behavioral attributes of the DPM to be compared against the judgment and experience of actual DOD/contractor personnel.

The second phase of the validation process included tests of DPM consistency and plausibility checks by examination of various scenarios generated by modification of model attributes. Several scenarios have been thoroughly invested (e.g., relaxing DOD monitoring capacity) and seem to provide reasonable and consisten results. The third phase, currently under way, involves statistical exploration of the underlying characteristics of the simulation model. Sensitivity analysis, through the application of regression and hypothesis testing techniques, is designed to yield information concerning the impact of different simulation parameters and initial conditions on the performance of the DPM. It will also provide greater insights into the workings of the model and previde a procedural description of its performance under different conditions.

An important outcome of this research is to demonstrate the use of the DPM as a 'laboratory' for designing and comparing alternative organizational linkages between the DOD and defense contractors with the ultimate objective being to improve procurement efficiency. Examples of how the DPM may be used include: a) exploring various ranges and cost sharing formulas involving target and ceiling costs; b) the use of preferred bidding lists or other methods of awarding contracts by the DOD; c) the withholding of progress payments; and d) modifying the nature of organizational interaction (i.e., multi-level pressure application) between the DOD and the contractor. The decision process model in this context becomes an invaluable management tool for identifying possible sources, and ultimately eliminating many of the inefficiencies inherent in the weapons acquisition process.

APPENDIX I

PM Manpower Assignment Sub-Model

a. Goal Achievement and Pressure Check Routine
b. Direct/Indirect Manpower Allocation Routine
c. High/Low Quality Manpower Allocation Routine
d. Project Specific Manpower Assignment Routine

Project Update Sub-Model

a. Schedule Update Routine
b. SQMM Balance Update Routine
c. Dollar Balance Update Routine
d. Quality of Performance Update Routine

Personnel Sub-Model

a. Hiring/Firing Routine
b. Labor Force Attrition Routine
c. Quality of Labor Force Update Routine

Backlog Determination Sub-Model

a. Capture Rate Determination Routine
b. New Proposal Generation Routine
c. New Contracts Awarded Routine
d. New Project Determination and Award Routine
e. New Project Attribute Assignment Routine
f. Accumulation of Existing Projects Routine
g. Backlog Calculation Routine

Cash Flow Determination Sub-Model

a. Direct Cost Determination Routine
b. Indirect Cost Determination Routine
c. DOD Billing Calculation Routine
d. Cash Flow Calculation Routine

Corporate Goal Adjustment Sub-Model

a. PM Corporate Allocation Routine
b. Corporate Cash Flow Pressure Routine

PM Goal Adjustment Sub-Model

a. Backlog Goal Modification Routine
b. Volume Goal Modification Routine

DOD Sub-Model

a. Schedule Pressure Routine
b. PM Quality Pressure Routine
c. Corporate Quality Pressure Routine

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CHAPTER 1: INTRODUCTION AND PROBLEM DEFINITION

1.1 Overview

This chapter will structure the many complex issues associated with weapon system procurement in a manner which classifies the problem areas and policies specifically relevant to our analysis. The focus is on market imperfections inherent in the weapons acquisition process and the resultant attempts of the DOD to influence contractor performance. DOD policies directed at improving contractor performance are categorized into three groups: a) Micro-contractual policies concerned with motivating efficient behavior by contractually providing the necessary incentives; b) Non-contractual policies concerned with structuring a competitive operating environment, and c) Macro-contractual policies concerned with cost estimation and evaluation procedures. DOD policies, operating procedures and problems associated with each category are briefly discussed and general trends in their use since World War II noted. The following chapter investigates in greater detail the theory and effectiveness of incentive contracting in the defense industry.

1.2 Market Failures in the Defense Industry

The objective of this section is to discuss in general terms why bilateral contractual arrangements have become such an integral part of contemporary DOD procurement strategy.[1] Mention will be made of market imperfections and distinguishing attributes of the defense industry which interfere with the usual allocative functions of a free market economy. The following discussion is not an all-inclusive analysis of these problems, but is meant to give structure to the complex issues associated with the need for contractual arrangements in the weapons acquisition process.[2] The next section focuses on the various contract-types utilized by the DOD to specify these arrangements.

1.2.1 Classical Market Imperfections

It is not difficult to distinguish the market environment of the defense industry from the classical model of perfect competition. Despite the temptation to discuss the few similarities, an attempt is made to classify the many differences into several broad categories.

The classical perfectly competitive economy may be characterized by five well-known assumptions:

1. Atomistic competition. The number of buyers and sellers in a given market is so large that any individual producer or consumer has a negligible influence on market performance. In addition, buyers and sellers in each market act independently.

2. Homogeneous products. All business firms in an industry produce products with indistinguishable attributes.

3. Perfect knowledge. All business firms and consumers in a given market possess full and complete knowledge of alternative production technologies and product attributes.

4. Free entry and exit. No legal, informational or institutional barriers exist which prevent a firm from entering or exiting a given market.

5. Profit (utility) maximizing behavior. Each seller (buyer) attempts to maximize profit (utility).

At the aggregate level, the supply side of the defense market does not appear to be highly concentrated relative to the U.S. economy as a whole.[3] The 100 largest DOD contractors are awarded approximately 70 percent of the total business with the top 25 controlling 50 percent.[4] In the U.S. economy, the 500 largest firms are responsible for 70 percent of total sales,[5] while 111 companies alone receive 50 percent.[6] Consideration, however, must be given to specific product areas (e.g., aircraft engines, guidance systems, surface radar systems) at various product levels (e.g., prime contractors, sub-contractors, parts suppliers) before conclusions concerning the structure of the defense industry can be drawn.

A review of 23 high technology product areas by Weidenbaum reveals a very high level of concentration at the prime contracting level.[8] The Bain high market concentration criterion suggests 22 of the 23 product areas studied are highly concentrated (i.e., the top 8 contractors received at least 70 percent of total awarded contracts in 22 of the 23 product areas studied). The less restrictive criterion of Kaysen-Turner (the largest 8 firms accounting for 50 percent of sales implies high concentration) shows all sectors of the defense industry studied are highly concentrated. Furthermore, when consideration is given to lower product levels (subcontractors and parts suppliers) concentration levels are high, and in some cases approach pure monopolies.[9] Therefore, when considering high technology product areas within the DOD industry, an oligopolistic market structure is observed rather than the atomistic market structure assumed by the classical model.[10]

The demand side of the defense market is often characterized as a monopsony, although it is generally recognized that limited competiton may exist among the three armed services in the procurement of specialized weapon systems.[11] In any case it is apparent that the classical assumption of atomistic competition is also violated on the buyer side of the defense market.

The requirement of independent and non-collusive behavior on the part of buyers and sellers is related to the assumption of atomistic competition. New weapon systems are typically instigated by a 'military requirement' recognized by defense planners, and/or a 'technological opportunity' identified by R&D specialists.[12] Whatever the source, cooperative behavior between the buyer and seller is commonplace and performed in a nonadversary environment. As Peck and Scherer noted: "Both contractors and sponsoring agencies, which are often the contractor's allies, believe their weapons programs are essential to the national defense."[13] Furthermore, Fox observed that "defense contractors are profoundly influential in the orientation and development of new program ideas."[14] Thus, in contrast to the classical assumption of non-collusive behavior, the development and production of advanced weapon systems necessitates a close working relationship between the contractor and purchasing organization.

The assumptions of homogeneous product attributes and perfect knowledge identify what are possibly the most apparent differences between the perfectly competitive market and the defense industry. The very nature of advanced weapon system development requires that product characteristics be unique and the result of newly developed (or applied) technology. At the extreme, the relevant

market may consist of a single, large-scale, highly sophisticated weapon system with incomparable attributes (e.g., the USS Nimitz). The need for heterogeneous product attributes and the application of imperfect knowledge in the production process is related to the concentrated structure of the industry. Even when duplicate mass production is required, the purchase of a new weapon system is often synonymous with the awarding of a 100 percent market share. This is a direct result of the vast expense associated with applying new (uncertain) technologies in advanced (unique) product development.

Free entry and exit in a given market facilitate the optimal use of economic resources by allowing the dynamic replacement of inefficient producers.[15] The most prominent barriers to entry in the defense industry include the need for specialized personnel and equipment, high overhead expenditures (e.g. R&D), large-scale capital investments, and 'brand-loyalty' for specific contractors often demonstrated by the military services. Likewise, barriers exist which prevent firms from leaving or diversifying out of the defense business; the most visible being a dependence on large-scale, long-term development and production contracts which help support high overhead rates and provide stable cash flow positions.[16] Another important factor which discourages an established firm from leaving the defense market is government sponsored R&D which frequently supports commercial (and more profitable) product lines.[17]

A final, and perhaps more typical market failure of the defense industry concerns the underlying goals which motivate decision makers within contracting organizations. The perfectly competitive classical model generally considers all decisions made by a given producer to be directed toward the maximization of profit. This implicitly makes a very strong assumption about the internal operation of the defense contracting firm -- an assumption on which much of this research is founded. The classical model views the firm as an autonomous organization with the singular organizational goal of profit and assumes that decision making units at all levels of the organization are implicitly or explicitly motivated toward its maximization. For reasons discussed later, the typical defense contracting organization is very unlike the classical 'black box' perspective of the firm where a singular goal structure is assumed to permeate all levels of the organization.[18]

1.2.2 Resource Allocation Decisions

Due in a large part to the market imperfections discussed above, the government has found it necessary to become directly and indirectly involved with various allocation decisions implicitly made by the classical market system. Through the process of equilibrium price determination, the

perfectly competitive free-market economy is assumed to be able to automatically perform various functions with respect to resource allocation, including:

1. What types of products to produce (i.e., product characteristics),
2. When to produce each product (i.e. current and future production schedules),
3. How to produce each product from available factor inputs in the most efficient (least-cost) manner,
4. The optimal level of current production for each product, and
5. How to distribute production among potential buyers.

The latter pair of allocative functions listed above are controlled indirectly by broad government policies. Unlike the perfectly competitive market where production level decisions are made by the simultaneous interaction of many buyers and sellers (through the equilibrium pricing mechanism), the aggregate level of production in the high-technology defense market is determined to a large extent by a third party -- the U.S. Congress via the level of appropriations designated for new weapon system development in the annual defense budget. Likewise, the distribution of advanced weapon systems to potential buyers is regulated by established law and congressional legislation.[19] While these macro-policies of the government are indeed important to the general functioning of the defense industry,[20] the concerns of this research focus on DOD contractual involvement with the first three allocative decisions.

There are two basic contract types utilized by the DOD to structure quasi-market relationships between price, product attributes, and schedule considerations. Although the primary purpose of both contract types is to perform the first two allocative functions (product definition and delivery dates), significant differences exist between the contracts concerning the need to influence the third (production efficiency). DOD procurement personnel have traditionally taken a 'hands-off' attitude toward direct involvement in the internal production processes of defense contractors.[21] This arms-length relationship has resulted in a heavy reliance on indirect contractual approaches to produce the desired products and performance characteristics. To the extent that production methods and product quality are inseparable, all contract types are equally concerned with production efficiency. However, important differences do exist between contract types in the assignment of financial liability resulting from production inefficiencies and/or inaccurate cost estimation.

The contract type which corresponds most directly to the free market environment involves contractually specifying the relevant product attributes, required delivery dates, and a fixed price. When the so-called 'fixed price' contract is utilized, the DOD is not directly concerned (except as mentioned above) with the contractor's production methods.[22] Instead, attention is focused on determining a minimum fixed

price which will induce a potential supplier to accept the responsibility (and risk) of producing the specified product by the agreed upon delivery date.

The fixed price type contract is theoretically appealing from the perspective of efficient resource allocation. The profit maximizing producer is automatically motivated to choose the most efficient (least cost) production method. Any unnecessary costs (i.e. deviations from the optimal production function) reduce profits to a level below the maximum attainable. The pricing mechanism, although artificial, performs one important allocative function: it provides maximum incentive for producing each product in the most efficient manner possible. Unfortunately, several practical difficulties limit the use of this contract type on high technology development programs.

The production of new weapon systems, as mentioned earlier, involves a great deal of uncertainty. Successful products require, by neccessity, the development and application of advanced technology. As weapon systems have increased in complexity and sophistication since WWII, uncertainty underlying development and production has increased dramatically. A major shortcoming of fixed price contracting centers around the assignment of the financial liability associated with this uncertainty entirely upon the contractor. Furthermore, the DOD has been, generally speaking, unwilling to pay a price commensurate with the risk. These complications make

fixed price type contracts less than satisfactory replacements for the allocative functions mentioned above, especially when applied to high-technology weapon systems.

To overcome the difficulties associated with the fixed price contract, the DOD has found it necessary to reduce the contractor's risk burden. The polar alternative with respect to risk assignment is the so-called cost-plus contract.[23] This approach involves, as before, contractually specifying product attributes and delivery schedules. However, unlike the fixed price contract, the final price is not specified ex ante. The price of a cost-plus contract is a function of the actual expenses incurred during the production or development process. The DOD automatically reimburses justified expenses incurred by the contractor. Note that the DOD assumes responsibility for the potential financial liabilities associated with production and development uncertainties.

Unfortunately, while possibly an improvement over the fixed price approach in advanced weapon systems procurement, the cost-plus contract is not without its practical difficulties. To begin with, the award of a cost-plus contract by the DOD is made to the firm, ceteris paribus, which submits the lowest cost estimate of the work to be performed. However, because of the cost sharing relationship, expenses in excess of the estimated amount are automatically reimbursed to the contractor. Thus, an obvious tendency exists for contractors

to bias initial cost estimates in a downward direction in order to be awarded a given contract.

In addition to over-optimistic cost estimates before the awarding of a contract, there is no explicit incentive for the contractor to choose the most efficient (least cost) production method after being awarded a cost-plus contract. The DOD is 'locked-into' a relationship in which final contract price is determined by incurred costs. In general, although the 'fixed price' contract ensures an efficient allocation of resources within the firm, when the basic cost-plus contract is utilized the pricing mechanism plays no role whatsoever in resource allocation. The absence of competition in the post-award operating environment combined with a price determination function which automatically links total income to total costs creates obvious problems for DOD procurement officials concerned with production efficiency and cost control. As shall be seen below, several broad policies have been undertaken by the DOD specifically addressing these problems.

In summary, due to the many market imperfections mentioned earlier (and the resultant absence of a competitive pricing mechanism), the government has found it necessary to perform many of the allocative funtions normally provided by a free market economy. This study is primarily concerned with the influence the DOD has on three specific allocative functions (what is produced, when, and how) through the use of bilateral

contractual agreements. The first basic contract type discussed utilizes a fixed pricing mechanism to ensure efficient production. The fixed price type contract is inappropriate, however, due to the magnitude and assignment of risk in the production process. The basic cost-plus contract was shown to avoid these problems by restructuring the risk sharing relationship and linking final contract price to actual expenses incurred. This contract type, however, also eliminates the direct incentive to produce efficiently and to control costs. Possible cost control problems associated with reimbursement-type contracts were classified into two categories: pre-award biased cost estimating procedures and post-award production inefficiencies.

1.2.3 The Risk-Sharing/Cost-Control Dilemma: An Overview

It is apparent that the operating environment of the defense industry is very unlike that described by the classical perfectly competitive model.[24] The DOD has been forced to rely on bilateral contractual arrangements as proxies for market allocation functions in order to obtain the desired products. Two interdependent areas of concern have been recognized: the need for some type of risk-sharing arrangement in contracts involving advanced weapon systems development and, as a result, the increased need for effective cost-control policies.

It is generally recognized that defense contractors would be unwilling to accept the risk inherent in the production of advanced weapon systems without modifying the level of financial compensation to significantly higher levels. Furthermore, the DOD is apparently unwilling to adjust prices to a level commensurate with the risk. The obvious solution involves the DOD accepting a portion of the risk in exchange for presumably more moderate pricing.[25]

The dilemma facing the DOD involves accepting a portion of the risk but at the same time controlling costs at an efficient level. Two basic approaches to this problem have been taken. The first approach requires direct participation by the DOD in structuring the contracting environment in such a way that cost efficiency is mandatory. Specific objectives of this approach include: improving cost estimation and evaluation procedures so that the most efficent producer is chosen and all relevant costs considered, monitoring all costs submitted for reimbursement to insure viability and, finally, increasing competition so that the relative efficiency of producers can be more accurately assessed.

The second approach requires much less effort on the part of the DOD in terms of influencing the contractor's operating environment. The objective is to motivate efficient cost performance by contractually providing the necessary financial incentives. The basic idea underlying this

approach involves the realignment of preferences (via modifications to the risk/reward structure specified in the contract) such that efficient behavior is in the best interests of the contractor. Ideally, relatively little DOD involvement other than contract specification is required.

It is now possible to classify DOD policies concerning the risk-sharing/cost-control dilemma into three categories:

1. Non-contractual policies directed at increasing competition before, during, and after the awarding of a given contract,

2. Macro-procurement policies directed at improving cost estimation, evaluation, and reimbursement procedures, and

3. Micro-contractual policies directed at providing incentives for efficiency and cost control.

The primary purpose of this research is to investigate the latter set of policies - contractual incentives directed at motivating efficient contractor behavior. The other two policy categories are briefly discussed later in this chapter. It should be mentioned that many problems inherent in the weapons acquisition process are not specifically addressed by these policies. Examples include possible managerial inefficiencies within the purchasing organization, non-optimal bargaining procedures utilized by the DOD, and

industrial organization problems concerning market behavior and structure. The primary concern is with internal inefficiencies of the contracting organization--specifically inefficiencies which are controllable and could be reduced or eliminated by management if motivated to do so. The objective of this research is to develop a methodological approach for analyzing tne relative effectiveness of various contractual incentive schemes more appropriate to the weapons acquisition process than the usual (static) normative modeling approach. The ultimate aim of this research is to provide improved insights into existing (and proposed) incentive schemes and policies.

The following section discusses the various contractual mechanisms available for use by the DOD. While several incentive-type contracts are introduced in this section, the next chapter analyzes the theory and effectiveness of incentive contracting in greater detail. The current chapter closes with a brief discussion of procurement policies specifically directed at the first two categories listed previously, increased competition and improved cost control.

1.3 DOD Contractual Procurement Policy

The purpose of this section is to introduce and define the various contractual mechanisms and related procurement policies the DOD has relied on since WWII.[26] The focus is on the risk-sharing relationship implied by the contract types and DOD policy towards its use. In addition, limited discussion is directed at allowable costs, profit, overhead, and billing considerations. Finally, general trends in the popularity of the two basic classes of contracts, fixed price and cost-plus, are discussed.

It should be mentioned at the outset that regardless of contract type, the basis for allowing or disallowing costs (both in the original estimates and in subsequent audits) is implicitly made a part of the contract language as determined by the Armed Services Procurement Regulations (ASPR).[27] These principles generally state that incurred cost to be allowable must be (1) reasonable in nature and amount, (2) allocatable to the contract and, (3) in accordance with generally accepted accounting principles and practices. This is important because the contracter is often responsible for providing information justifying the reasonableness and legitimacy of costs. Prices may be adjusted de facto if this data is not as certified.[28]

1.3.1 Fixed Price Contracts

Firm-Fixed-Price (FFP)

The firm-fixed-price contract, as mentioned earlier, most nearly approximates the buyer-seller relationship in an open economy. Essentially it involves an agreement prior to the execution of the definitive contract of a price to be paid by the purchasing service for the specified articles to be delivered by the contractor. The price remains firm for the life of the project. As such, the contractor assumes the maximum business risk and is provided with the maximum incentive to control production costs. Exhibit 1.a demonstrates the relationship between the contractor fee (price) and total costs. This contract-type is applicable for procurements involving products for which there is a reasonable price comparison, a standard design, adequate prior manufacturing experience, and a short delivery schedule.

Fixed Price with Escalation

The fixed price contract with escalation is similar to the FFP except that the ultimate contract price may be (as determined by the escalation prevision) higher or lower than the original price. This contract type reduces the risk to the contractor by adjusting the price dependent on specified contingencies involving factor inputs. Note that the contract does not offer protection from cost mis-estimation or production inefficiencies. This type of contract is

utilized when doubt exists over market stability; the contingency associated with the instability can be specified with an escalation clause. The DOD generally discourages this type of contract due to the difficulty of ensuring that the contractor eliminates allowances previously made for the uncertainty and the required efforts necessary to administrate the provision.[29] The fixed price with escalation is applicable, however, when specific identifiable inputs are utilized in predictable amounts over extended time periods.

Fixed-Price-Incentive (FPI)

Broadly speaking, an incentive contract provides for the revision of the agreed target price through a formula for the sharing of the difference between actual costs and the target costs. The contractor is reimbursed for actual incurred costs (below ceiling costs); target profit is adjusted by the sharing formula dependent on the relationship of actual to target costs. The FPI contract requires the negotiation of (1) a target cost, (2) a target profit (actual profit if work performed at target costs), (3) a price ceiling (the maximum amount for which the government is liable), and (4) a sharing formula (the arrangement for sharing of incurred costs below the ceiling price).[30] Note that a profit floor is not established; any costs in excess of the price ceiling are the responsibility of the contractor. The actual profit is decreased in the event of

an overrun and increased in the event of an underrun. This relationship is demonstrated in Exhibit 1.5. Within the boundary of the price ceiling, the government and the contractor are sharing the financial risk. The fixed-price incentive contract is applicable when a reasonable, contingency-free target and ceiling price can be established.

Fixed Price with Redetermination

This type of contract provides for a recalculation of the price after a specified period of production.[31] Prospective contracts provide for redetermination during production, typically after 30 to 40 percent of contracted costs have been incurred. Retroactive contracts adjust price after the required work is completed.[32] Note that in either case the government reduces the financial risk to the contractor up to the point of redetermination afterwhich the contractor assumes the risk of a FFP contract. With retroactive redetermination, a price ceiling is specified with the awarding of a contract and subsequent negotiations adjust the price within this ceiling. Except for this ceiling, little incentive exists for cost control. Therefore, retroactive redetermination is limited to small dollar R&D contracts. Prospective redetermination is applicable when firm prices can be established for only a limited portion of the contract period. While incentives for cost-control exist after determination of the fixed price, there are serious doubts as to whether a cost conscious

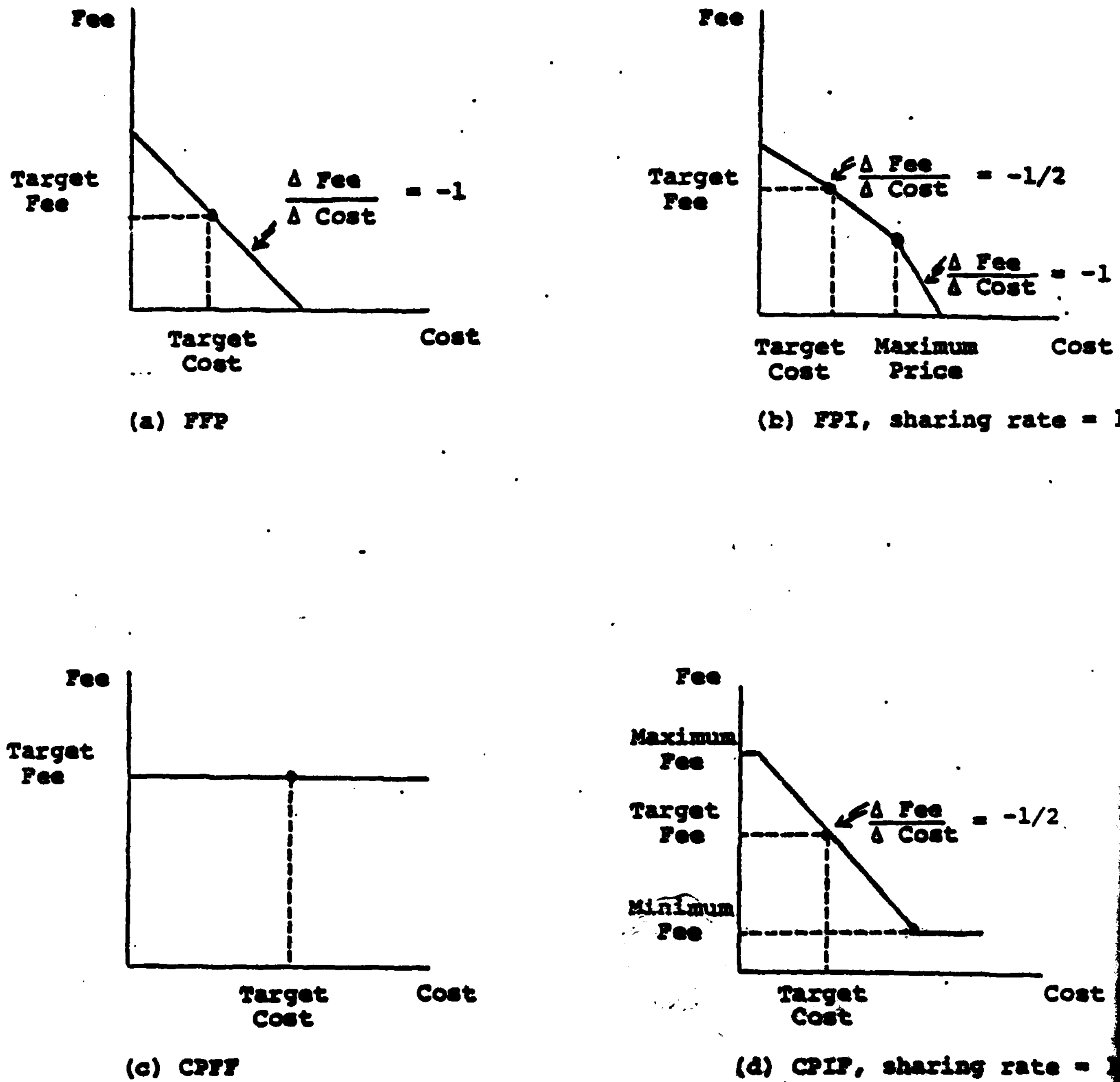

Exhibit 1

Comparison of Four Major Contract Types

climate is encouraged before redetermination.[33]

Firm Fixed Price Level of Effort

This type of contract obligates the contractor to provide a specified level of effort over a stated period of time. The fixed price, in effect, is exchanged for effort rather than products or results. The contractor assumes little risk because the work to be performed cannot be defined and is essentially complete when the required effort has been expended. This type of contract is applicable for R&D or other exploratory projects where the level of effort can be agreed upon in advance and identified.

1.3.2 Cost-Plus Contracts

Cost-Sharing

The cost-sharing contract is an arrangement under which the contractor receives no fee but is reimbursed for an agreed upon portion of the allowable costs. This type of contract is applicable to jointly sponsored R&D projects where the contractor is expected to benefit sufficiently from the proposed work to merit cost-sharing.

Cost Reimbursement Without Fee

This type of contract provides for the recovery of acceptable costs only and makes no provision for payment of a fee. The performance of the contractor is governed on a 'best effort'

basis. The cost without fee contract is for the purchase of facilities which will be used in conjunction with other DOD procurements or arrangements with non-profit institutions.

Cost-Plus-A-Fixed-Fee (CPFF)

The CPFF contract provides for the recovery of allowable costs incurred in connection with the contract plus a predetermined fixed fee representing profit. The fee is fixed regardless of whether the actual costs are higher or lower than the original estimated costs unless the scope of the work to be performed is modified (see Exhibit 1c). Little risk is associated with this type of contract for the contractor because an increase in cost does not affect the amount of fee received.[35] Likewise, there is little 'built-in' incentive to control costs. The CPFF contract is considered applicable only when the uncertainties involved in contract performance are of such magnitude that cost estimates cannot be established with sufficient reasonableness to permit use of any other contract type (i.e. fixed or incentive). Examples typical of the CPFF criteria include: preliminary research where the necessary level of effort is unknown, or in development and test programs where an incentive-type contract is not practical.

Cost-Plus-Incentive Fee (CPIF)

A CPIF contract is similar to the CPFF contract except that the fee is adjusted based on the relationship of actual to

target costs. This type of contract requires negotiation of (1) a target cost, (2) a target fee, (3) a minimum and maximum fee, and (4) a fee adjustment formula based on actual costs relative to target. Note that this differs from the FPI contract in that price ceilings are not specified, and a minimum profit is assured (see Exhibit 1.d). The objective of the CPIF contract is to reduce uncertainty to the contractor by stipulating a minimum fee but to provide an incentive for efficiency by allowing upward adjustments based on performance. The CPIF is applicable to situations in which the uncertainty is unacceptably high for a FPI contract but too low to merit a CPFF contract; for example, development programs and test activities.[36]

Cost-Plus-Award-Fee (CPAF)

The CPAF contract contains a special fee provision that provides a means of establishing performance incentives in contracts which are not susceptible to finite measurement. The fee consists of two components: (1) a fixed amount, or base fee, which does not vary with performance, and (2) an award amount determined by the DOD which is intended to provide motivation for improved performance on the basis of criteria established in the contract. The award fee may be earned in whole or in part as unilaterally and subjectively determined in the DOD at successive stages of contract completion. The subjective nature of the award process and required involvement of the DOD in monitoring and evaluating contractor

performance has led many defense procurement specialists to consider the CPAF contract a management technique rather than a formal contractual arrangement, per se.[37]

1.3.3 Miscellaneous Contract Types

Time and Material Contracts

The time and material contract provides for payment to the contractor on the basis of direct labor hours at specified hourly rates (including direct costs, overhead, and profit) and materials at cost. This type of contract is applicable when accurate estimates of the scope and cost of work to be performed are impossible. The time and material contract has limited usage due to the lack of incentive to control the amount or quality of direct labor. Higher usage of direct labor necessarily increases the absorption of overhead and the level of profit.[38] Its use is therefore restricted to small procurements.

Performance Incentive Contracts

This contract type is merely a modified version of the incentive-types discussed above. The objective is to provide incentives for multi-dimensional performance factors including quality and time of availability as well as costs. The specific performance goals, measurement criteria, and the profit formula generally require considerable negotiation and administrative efforts.

Letter Contract

The letter contract is a preliminary contract which is issued prior to the negotiation of a complete agreement between the DOD and the contractor. This type of contract subjects the contractor to considerable financial risk but is utilized for expediency purposes only and is usually short-lived. Its use has been discouraged by the DOD.[39]

Indefinite Delivery Contracts

This contract is designed for usage when the exact delivery date is unknown at the time of contract negotiation. The indefinite delivery contract is applicable for the procurement of commercial goods and services where little R&D is required.

1.3.4 Related Considerations

Criteria for Contract Selection

Although no firm rules exist which absolutely determine the selection of the proper contract type, the following guidelines have been expressed in the DOD Incentive Contracting Guide:

> Firm-Fixed-Price. Performance has already been demonstrated and technical and cost uncertainty is low.

Firm-Fixed-Price (With incentives added). Improved performance or schedule is desired and technical and cost uncertainty is low.

Fixed-Price-Incentive (Cost incentive only). Confidence in achieving performance is high but cost and technical uncertainty can be reasonably identified.

Fixed-Price-Incentive (Multiple incentive). Improved performance is desired and technical and cost uncertainties are reasonably identifiable.

Cost-Plus-Fixed-Fee. 'Level of effort' is required or high technical and cost uncertainty exist.

Cost-Plus-Award-Fee. Conditions for use of a CPFF are present but improved performance is also desired, and performance cannot be measured objectively.

Cost-Plus-Incentive-Fee (Cost incentive only). A given level of performance is desired and confidence in achieving that performance level is reasonably good, but technical and cost uncertainty is excessive for use of a fixed-price incentive.

Cost-Plus-Incentive-Fee (Multiple incentive). Expectation of achieving an acceptable performance is good but improvement over that level is desired and technical and cost uncertainties are excessive for use of fixed-price-incentives.[40]

Profit Regulations

The estimated profit included in a proposed price is generally known by the DOD and is subject to regulation, except in the case of FFP contracts negotiated without reference to cost breakdown. Restrictions are placed on the amount of profit which may be negotiated on a CPFF or a CPIF in the Armed Services Procurement Regulations (ASPR). The negotiated profit (or fee) cannot exceed 15 percent of total costs for R&D contracts and 10 percent of total costs for all others.[41]

In 1963 the DOD introduced a new method for fee or profit determination in any procurement in which the price is based on an analysis of cost.[42] This method, known as the weighted guidelines method, is used by DOD contracting officers to establish profit objectives in negotiations with contractors based on specific profit factors that have been assigned a weight range.[43] A total dollar profit is first computed (based on assigned percentages within the range) for each cost element in the "Contractor's Input To Total Performance";[44] the dollar total is then translated into a (weighted) composite profit percentage for this factor.

A similar approach is taken in assigning weights for assumed risk, performance record, and selected factors in order to produce a total profit percentage. The percentage is then applied to the total contract cost to determine the dollar profit objective.

Finally, under the terms of the Renegotiation Act of 1951, which is applicable to all DOD contracts whether or not incorporated into the contract language, over-all combined annual profits earned by a contractor on total renegotiable sales are subject to annual review by the Renegotiation Board.[45] If excess profits are discovered in a given year, the Board notifies the contractor of the amount considered excessive and requests a refund.

Billing Procedures

Under cost-plus contracts, the DOD pays contractors on a current basis for costs incurred and a pro rata amount of the fee, if any, applicable to the costs. The contractor usually submits an invoice itemizing the cost details once a month to the Contract Auditor, who processes the invoice for payment. Large-scale fixed price contracts also allow for progress payments to be made to the contractors. The usual approach is to pay contractors once a month for 80 percent of the costs incurred against a contract. The DOD generally does not make a detailed audit of the costs submitted for progress payments short of insuring that payments do not exceed 80 percent of costs incurred, and the balance of unliquidated payments is consistent with the undelivered portion of the contract.

Overhead Negotiation[46]

As mentioned earlier, certain DOD contract-types (particularly cost-plus contracts) require de facto audits of all costs and expenses to ensure accordance with Section XV of the ASPR. While generally no difficulty is involved with applied material and direct labor expenses, overhead does require negotiation. At the start of each fiscal year, preliminary billing rates and liquidation bases are established for various functional categories of overhead, including

applied overhead, engineering, and general administrative expenses.[47] The overhead billing rates are based on forecasts of the forthcoming year. At the close of the fiscal year the contractor must submit rates based on actual incurred expenses to the Contracting Officer. Retroactive review and negotiation then take place to establish the actual overhead billing rates on work performed in the previous year.[48]

1.3.5 Extent of Use of the Basic Contract Types

The ASPR, orginally published in 1947, advocated the use of fixed-fee type contracts rather than cost-plus due, in part, to the alleged profiteering which occurred during WWI through the widespread use of cost-plus-a-percentage-of-cost contracts. This peverse profit-cost relationship allowed for higher levels of profit as actual costs increasingly exceeded original estimates. The use of this contract type was eventually disallowed by the First War Powers Act of 1941.[49]

While 45 percent of the supply contracts greater than $10 million were CPFF in WWII, as the war progressed its use declined.[50] In 1952, 82 percent of defense prime contracting awards were of the fixed-price type. With the end of the Korean War defense needs shifted from standard military ordinance items to sophisticated weapon systems. The risk associated with development and production required the

increased use of cost-reimbursement contracts. The use of cost-plus type contracts increased from 18 percent of total contracts awarded to prime contractors in 1952 to 43 percent in 1960.[51]

In response to criticism of extreme cost overruns of several major weapon systems, Defense Secretary Robert McNamera attempted to control costs by shifting greater risk to the contractor and to provide profit incentive more commensurate with the risk. The use of fixed price contracting increased from 57 percent of defense prime contracting awards in 1960[53] to 79 percent in 1966.[54] Due to the perceived failure of these policies to improve cost performance (discussed in the next chapter) the 1970's saw a revision back to the government assumption of risk through the use of cost reimbursement contracts for research and development work.[55]

As previously mentioned, in addition to using various contract types to induce efficient contractor behavior, the DOD has attempted to control costs by modifications to non-contractual and macro-level aspects of procurement policy. The following section discusses these policies categorized into two groups; those concerned with increasing competition and those concerned with improving cost estimation and evaluation procedures. Additional discussion of incentive contracting is postponed until tne next chapter.

1.4 Non-Contractual and Macro-Level Procurement Policies

1.4.1 Non-contractual Policies Directed at Increasing Competition

A common characteristic of weapon system procurement is the lack of direct competition between producers, both before and after the awarding of a contract. This condition is exasperated when long-term high-technology projects are considered which require preliminary R&D before full scale production contracts can be awarded. The producer performing the initial R&D is often locked-into subsequent production contracts -- i.e., the buyer-seller relationship evolves into a bilateral monopoly. Attempts have therefore been made by the DOD to instigate direct competition during earlier and later stages of the procurement process.[56]

Prototyping, or the actual development of a full-scale working system by different sources before awarding the production contract, is intended to increase the level of direct competition, as well as, demonstrates conceptual feasibility of product design. In addition to providing the DOD with the opportunity to evaluate capabilities in a competitive demonstration, the prototype at an advanced stage of development can be used to demonstrate whether the system actually satisfies a current or a future need. Significant cost efficiencies are also possible via the early identification of major design changes or defects. The major shortcoming

of prototyping is that it substantially increases the time and costs associated with development. Its use, therefore, has been recommended for large quantity weapon systems which require substantial innovation but have a low ratio of development to total acquisition costs.[57]

Many different policies of the DOD have attempted to increase the level of competition after the initial awarding of a production contract. 'Breakouts' are directed at increasing competition in the purchasing of components and spare-parts by reprocurement from sources other than the primary contractor. 'Second-sourcing' involves the competitive reprocurement of complete weapon systems. While a single firm under 'second-sourcing' usually performs the initial R&D, several production sources may be developed and maintained by DOD evaluation and dissemination of required technical information to other producers. The shortcomings of this approach include the possible redundancy (and associated expense) of multiple production facilities, and the required maintenance of a large technical staff by the DOD.

'Leader-follower' procurement is similar to second-sourcing but involves the DOD contracting with an existing producer to provide the technical assistance necessary to enable another firm to establish production capability. Although this policy is usually implemented to expand production capacity rather than to increase competition, its use is

constrained due to the expected problems of motivating existing producers to transfer the required technical expertise to rival firms.[58]

The most comprehensive policy attempt to introduce competition into the post-award operating environment involves decomposing the weapon system production process into discrete stages and soliciting competitive bids as each stage is completed. The decoupled stages include development, prototyping, initial production, follow-on production, and during follow-on production. In addition to the problem of inducing firms to willingly transfer highly-technical proprietary information, there is the increased possibility that significant production delays will occur if reprocurement is attempted.

1.4.2 Macro-Procurement Policies Direct At Improved Cost Estimation and Evaluation

DOD attempts to induce efficient behavior have included development of several policies specifically directed at improved cost control. Rather than discuss the detailed monitoring and audit procedures of the DCAA and the GAO, the discussion here instead focuses on broad policy attempts to eliminate 'buy-in' behavior (i.e., submission of biased estimates) and increase contractor cognizance of total system costs.

In response to the cost-overruns of the 1950's, 'total-package' and 'multi-year' procurement policies were implemented

by the DOD. The basic idea was to award full production contracts (including R&D in the case of total-package procurement) for several years at a time. Alleged benefits to this approach included the prevention of buy-ins due to the scope of the contract (at least in the case of total-package procurement), as well as several substantial cost reduction features. For example, start-up costs and capital expenditures could be prorated (amortized and depreciated respectively) over several years; also, training and turnover costs associated with fluctuating labor force requirements could be reduced. In addition, the total-package procurement program required the contractor to formulate initial design concepts with an increased concern for future efficient production feasibility.

Unfortunately, both policies have practical constraints which severely limit their use as applied to advanced weapon system procurement. Rarely are design and system specifications sufficiently stable enough to allow long-term contractual arrangements.[59] Furthermore, the congressional budgeting process combined with the DOD's nature of constantly reassessing current and future service needs does not provide an environment particularly conducive to long-term contractual obligations. Thus, total-package and multi-year policies are limited to weapon systems not subject to rapidly changing technology or military requirements. Finally, and perhaps most importantly, the use of long-term contractual agreements seriously underminds the efforts to

improve the post-award competitive environment.[60] The Navy, in fact, concluded that any savings from multi-year contracts in ship building are offset by the lack of competition.[61] As a result of these shortcomings, the DOD discontinued use of total-package procurement on complex weapon system procurement in 1971.[62]

'Life-cycle-costing', established in 1970, was intended to extend relevant cost considerations of the contractor (and procurement personnel) beyond acquisition costs and to also include support and operating costs. The purpose of life-cycle-costing is to ensure that total costs, ownership as well as acquisition costs, are evaluated in the selection and development of new weapon systems. A complementary policy is the 'design-to-costs' concept which establishes rigorous cost objectives (based on life-cycle considerations) equal to performance quality and schedule considerations. Major problems have resulted in practice, however, due to the inaccuracy of life-cycle cost estimates and the need for detailed information when establishing goals and making tradeoffs in the design-to-cost phase of new system development.[63]

1.5 Conclusion

This chapter has attempted to structure the many complex issues associated with weapon systems procurement in a manner which clarifies the problem areas and policies specifically relevant to our analysis. In order to accomplish this, generalizations were required that often disguised the multi-dimensional and interdependent nature of problems inherent in the weapons acquisition process. A comprehensive analysis of these many complexities is clearly beyond the scope of this research. It is felt, however, that the chosen area of study, determinants of defense contractor behavior, has generally been neglected, and as a result is the underlying cause of many policy failures. A better understanding of extra-contractual and non-market factors which influence decision making in defense contracting organizations is required before more effective procurement strategies (of any type) can be developed.

DOD policies directed at improving contractor cost efficiency have been categorized into three groups:

1. Non-contractual procurement policy concerned with structuring a competitive operating environment.
2. Macro-contractual policies concerned with cost estimation and evaluation procedures, and
3. Micro-contractual policies concerned with motivating efficient behavior by contractually providing the necessary incentives.

Although some overlap cannot be avoided, this research is primarily concerned with investigating the latter set of policies. The following chapter discusses in greater detail the theory and effectiveness of incentive contracting.

Footnotes

[1]The DOD wrote 10 million contracts (5000 per working hour) in 1970.

[2]J. Ronald Fox, Arming America: How the U. S. Buys Weapons (Cambridge, Mass.: Harvard University Press, 1974), p. 224.

[3]For a comprehensive, though somewhat dated, review of the complex issues associated with weapons acquisition, see M.J. Peck and F.M. Scherer, The Weapons Acquisition Process: An Economic Analysis (Cambridge, Mass.: Harvard University Press, 1962); Scherer, The Weapons Acquisition Process: Economic Incentives (Harvard University Press, 1964). For a contemporary discussion of macro-level problems see J.S. Gansler, The Defense Industry (Cambridge, Mass.: MIT Press, 1980).

[4]In the case of NASA, the industry concentration is slightly higher. In 1966 the top 100 contractors received 91 percent of the total awarded contracts; NASA Annual Procurement Report: Fiscal Year 1966 (U. S. Government Printing Office).

[5]Gansler, op. cit., pp. 36-37.

[6]"Fortune 500" listing, Fortune, 1975.

[7]R.J. Barnet and R.E. Muller, Global Reach: The Power of the Multinational Corporation (New York: Simon and Schuster, 1974), p. 230.

[8]There are extreme difficulties associated with the identification of SIC numbers on the defense industry. See J. W. McKie, "Concentration in Military Procurement Markets: A Classification and Analysis of Control Data," Rand Corporation report RM-6307-PR (Santa Monica, Calif., 1970).

[9]M. L. Weidenbaum, "The Military/Space Market: The Intersection of the Public and Private Sectors," U. S. Senate Hearings, Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary, 90th Congress, second session, pursuant to S.R. 233, June 17 and 21 and September 10, 1968 (Washington, D.C.: Government Printing Office, 1969).

[10]It should be mentioned that a similar study by Weidenbaum of U.S. Air Force procurement markets revealed the opposite conclusion -- high concentration ratios were not observed and substantial competition was assumed to exist. However, this particular study was not restricted to high technology product areas and therefore included such categories as containers, petroleum, construction and clothing. See M.T. Weidenbaum, "Competition In High Technology Government Markets", Working Paper 6713, NASA Grant No. NSG-342, November, 1967.

[11]For example, see National Security Industrial Association, Defense Acquisition Study, Final Report, Washington, D.C., July 1, 1970.

[12]Gansler, op.cit., p. 32.

[13]Peck and Scherer, op.cit., p. 248.

[14]Fox, op.cit.

[15]For a comprehensive listing of the many barriers to entry and exit see Gausler, op.cit. pp.46-50. For a historical perspective see William L. Baldwin, The Structure of the Defense Market 1955-1964, (Durham, N.C.: Duke University Press, 1967).

[16]Efforts to diversity out of the defense business by major contractors have had very little success. See, for example R. DuBoff, "Connecting Military Spending to Social Welfare: The Real Obstacles", Quarterly Review of Economics and Business, Spring 1972.

[17]A good example of this is provided by General Electric and Pratt & Whitney, the major suppliers of large military jet engines, both having substantial commercial jet engine divisions.

[18]The underlying motives of defense contractors has been the focus of many exhaustive studies, some of which will be discussed later in this research. For a brief introduction ot the problem see Scherer, op.cit., pp. 510.

[19]See Fox, op.cit. Chapter VII for additional discussion of congressional influence on weapons acquisition. See Gausler, op.cit. for a contemporary discussion of distribution related (esp. multinational) considerations.

[20]The importance of these broad macro policies is the central theme of Gansler, op.cit.

[21]This position is largely a facade due to wide-spread government ownership of production and test facilities and the sponsoring of IR&D.

[22]This cursory defination of a fixed price contract is for expository purposes only. A more complete analysis is provided in the next section.

[23]Again, the defination of cost-plus contracts in this context is purposely vague and incomplete. The following section will define the various contract types in greater detail.

[24]It should be mentioned that the collusive non-adversary nature of the buyer-seller relationship makes the defense industry very unlike the classical models of imperfect competition as well.

[25]Acceptance of risk in this respect is synonymous with some form of cost reimbursement.

[26]Much of the discussion in this section relies on the detailed regulations and procedures found in the Defense Procurement Handbook, the Armed Services Procurement Regulations, and the DOD Incentive Contracting Guide prepared by the Office of the Secretary of Defense.

[27]Armed Services Procurement Regulation, Section XV, part 2.

[28]Audits of these procedures are periodically performed by the General Accounting Office (GAO) and the Defense Contract Audit Agency (DCAA).

[29]Armed Services Procurement Regulation 3-404.3.

[30]While incentives concerned with costs are most common, incentive features may apply to technical performance and schedule considerations as well. The 'multiple-incentive' contract is discussed briefly under Performance-Incentive Contracts.

[31]Armed Services Procurement Regulation 3-404.5-7.

[32]In practice, the redetermined price may be prospective, retroactive or both.

[33] Scherer, op.cit. p. 138, found "a distinct historical tendancy for profit amounts to be reduced rather than increased in redetermination when costs have been decreased [lower than estimated.]" In 84 percent of the cases studied when the redetermination price was less than the base price, the profit was decreased. A similar tendancy was also observed during WWII by J.P. Miller, Pricing of Military Procurements (New Haven: Yale University Press, 1949), p. 138.

[34] This diagram, slightly modified appears in J.G. Cross, "A Reappraisal of Cost Incentives In Defense Contracts", Western Economic Journal (June, 1968) pp. 205-225.

[35] In addition, the risk to the government of making a 'windfall profit' award is also eliminated.

[36] Armed Services Procurement Regulations, 3-405.4(c).

[37] This perspective of award-type Contracts is put forth and established by Professor Raymond Hunt in two related studies: 'R&D Management and Award Fee Contracting', Journal of the Society of Research Administrators, Summer, 1974 pp. 33-39 and "Use of the Award Fee in Air Force System and Subsystem Acquisition", Final Report to the AFBRMC, Contract No. F33615-78-C-5230, April 1980.

[38] The time and materials contract closely resembles the cost-plus-a-percentage-of-cost contracts that were outlawed by the First War Powers ct of 1941 and again by the Armed Service Procurement Act of 1948.

[39] Department of Defense (1971). Directive 5000.1, Acquisition of major defense systems. July 13.

[40] Office of the Assistant Secretary of Defense (Installations and Logistics), DOD Incentive Contracting Guide, 1969, p. 45.

[41] Armed Services Procurement Regulation, 3-405.4(c).

[42] Ibid., 3-808.4.

[43] For a thorough analysis of the factors used in the weighted guidelines method, see J.E. Boyett and D.E. Strayer, "Analysis of Cost and Non-Cost Negotiated Profit Factors in Department of Defense Contracting", Prepared for the DASD (I&L) Profit '76 Study by the Air Force Business Research Management Center and the Air Force Business Institute of Technology.

[44] Includes Direct Materials, Engineering Labor & Overhead, Manufacturing Labor & Overhead, and General Administration Expenses. ASPR 3-808.4V p.3:143.

[45] Scherer, op.cit., pp.253.

[46] The procedures and policy for the establishment of overhead rates on cost-plus contracts is found in ASPR Section III, Part 7.

[47] Rates are also commonly established for IR&D, Bid & Proposal, etc.

[48] For a contemporary analysis of the overhead negotiation process, see P.J. Lynch and J.M. Pace, "An Analytical View of Advance Incentivized Overhead Agreements In The Defense Industry" Master's Thesis, Air Force Institute of Technology, September, 1977.

[49] Public Law No. 354, 77th Congress, 1st session (55 Stat. 838-839).

[50] U.S. War Production Board, Bureau of Program and Statistics, Cost Plus Contracts in the War Program (March 8, 1945), Table I (cited in Scherer, op.cit. p. 142.)

[51] House Committee on Armed Services, Special Subcommittee on Procurement Practices of the Department of Defense, Hearings Pursuant to Section 4, Public Law 86-89 (1960), p. 133; (cited in Scherer, op. cit., p. 143).

[52] Office of the Secretary of Defense, Military Prime Contract Awards and Subcontract Payments, July 1961 - June 1962, p. 41 (cited in Scherer, op. cit., p. 143).

[53] Scherer, op. cit., p. 243.

[54] Office of the Assistant Secretary of Defense (Comptroller), Directorate of Information Operations, Military Prime Contract Awards, Fiscal Year 1970 (cited in Fox, op. cit., p. 236).

[55] Fox, op. cit., p. 238.

[56] For an examination of military procurement policies from 1947 to the present, see B. R. Lenk, "Government Procurement Policy: A Survey of Strategies and Techniques", Office of Naval Research, Contract No. N00014-75-6-0729, May 1977.

[57]General Accounting Office (1969), "Evaluation of two proposed methods for enhancing competition in weapons systems procurement" (cited in Lenk, op.cit. p. 19).

[58]Lenk, op.cit. p. 20.

[59]In addition, the contractual specification of long-term contracts at an early stage of development or production may inhibit desired and beneficial technological innovations. See T.K. Glennau Jr. "Innovation and Product Quality Under the Total Package Procurement Concept," The Rand Corporation, 1966.

[60]See, for example, R. E. Johnson and J.W. McKie "Competition in the Reprocurement Process", The Rand Corporation, 1966.

[61]Lenk, op.cit. p. 16.

[62]Department of Defense, Directive 5000.1, "Acquisition of Major Weapon Systems," July, 1971.

[63]Lenk, op.cit., p. 22.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to discuss in greater detail the theory and effectiveness of incentive contracting in the weapons acquisition process. Due to the vast amount of literature relevant to incentive theory and the scope of the problem under analysis, we are necessarily eclectic in our review. Several models are discussed in the following section which demonstrate the 'real world' considerations which have been incorporated into the general analysis of incentive contract theory. The focus is on the specification of contractual parameters and contract execution rather than the contractor identification and selection process--although many considerations are relevant to both problems.[1]

It is important to note that incentive contract theory is concerned with the ex ante specification of contractual parameters in order to influence contractor performance. This, of course, requires (among other things) assumptions concerning the ex post behavior of the firm after the contract has been awarded and specified. There has been, however, a notable absence of research and scrutiny directed at these central assumptions. As shall be argued below, until additional attention is focused on the ex post organizational decision process of the contracting firm, progress

towards understanding the apparent ineffectiveness of incentive contracts as applied to advanced weapon system procurement will be delayed.

2.1.1 Parameters of Incentive Contracts: The Basic Model

The standard model of incentive contracting can be represented in algebraic terms where α is the contractor's sharing proportion, C_A is the actual cost incurred by the contractor, C_C is the ceiling cost, C_T is the <u>target</u> cost, and Π_T is the target profit written into the contract.[2] The total fee received by the contractor and the total outlay of the government, F and G respectively, may be written as:

$$(1)\quad F = \Pi_T + \alpha(C_T - C_A) + (C_C - C_A)$$

$$\text{where} \quad C_C = C_A \quad \text{if} \quad C_A < C_C, \text{ and}$$

$$(2)\quad G = \Pi_T + C_T + (1 - \alpha)\,(C_A - C_T)$$

$$\text{where} \quad C_A = C_C \text{ if } C_A \geq C_C.$$

This standard representation ignores any product performance or scheduling considerations which are often written into defense contracts. It is important to note that the variables subject to negotiation include Π_T, C_T and C_C, as well as α.

The above model is convenient because it allows for the analysis of CPFF, FFP, and FPI contracts within the same linear fee schedule framework. For example, by assigning values of 0 and 1 to α, CPFF and FFP contracts can be

represented, respectively.[3] By allowing α to vary between 0 and 1 a basic FPI contract is represented. If a cost overrun ($C_A > C_T$) occurs, the contractor is required to pay $\alpha(C_T - C_A)$ via a reduction in fee while the DOD pays $(C_A - C_T)$
$(1 - \alpha)(C_T - C_A)$. Note that with a CPFF contract ($\alpha = 0$) C_T is necessarily equal to C_A, ex post. Because 'incentive' contracts are usually associated with $0 < \alpha < 1$, much of the analysis in the following literature review focuses on the optimal specification of α.[4]

2.1.2 General Considerations

It will be helpful to give a brief overview of the complications which are implicit or incorporated into the basic model described above before discussing in greater detail several theoretical approaches to incentive contract specification. These complications can be categorized into four general areas: structural, motivational, informational, and behavioral. Enhancements in the form of motivational, informational, and (to a much lesser extent) behavioral assumptions have been analyzed with varying degrees of emphasis in the models discussed below. However, important considerations implicit in the structural formulation of the incentive contracting model must first be recognized.

Equation (2) defines the total expenditures, G, required of the DOD for a given contract. However, it is commonly

recognized that the DOD may be interested in other objectives in addition to the minimization of G. Examples include improving weapon system performance capabilities, insuring the timeliness of delivery, maximizing productive efficiency (i.e. minimizing C_A), constraining contractor profits (Π_T), and reducing cost overruns ($C_A - C_T$). The incentive contracting problem may at first glance be perceived as the optimal determination of α given the goals of the DOD. However, the conflicting nature of DOD contracting objectives combined with parameters other than α subject to negotiation make this approach clearly unrealistic--even within the unburdened model formulated thus far. A simplistic example demonstrates this point.

Assume for the moment that the contracting firm is solely concerned with maximizing the expected value of the fee received in the current contract. Likewise, assume the DOD is concerned with implementing an incentive scheme which minimizes the required outlays necessary for the development and delivery of a given weapon system by reducing cost overruns. When a sharing proportion greater than zero (i.e. an incentive-type contract) is negotiated or required by the DOD, the risk burden of potential cost overruns assumed by the contracting firm is no longer negligible. The classical fee-maximizing firm is expected to react, ex post, by choosing the production function which minimizes C_A.

Minimizing C_A is, of course, synonymous with minimizing cost overruns ($C_A - C_T$) and total government outlays (G), _ceteris paribus_.

However, the fee-maximizing firm may also be expected to react to $\alpha > 0$, ex ante, by modifying other contractual parameters subject to negotiation. In order to compensate for the increased risk burden, the contractor may attempt to negotiate upward adjustments in target costs C_T target profit Π_T, and/or ceiling costs C_C. A non-zero sharing proportion may very well decrease cost overruns ($C_A - C_T$) by providing perverse inducements to increase C_T, in addition to the desired decrease in C_A. The possible increase in C_T combined with possible increase in Π_T and C_C may ultimately result in greater total cost to the government when an incentive-type contract is utilized.[5]

Thus, the structural form of the basic model suggests that important DOD goals are possibly in conflict and tradeoffs may be required. Furthermore, isolating the effects of a given policy change necessarily requires strong assumptions directed toward potential contractor response - ex ante as well as ex post.[6] Consideration must obviously be given to the existence of multiple DOD goals as well as multiple negotiable parameters when assessing the relative effectiveness of various incentive contracting schemes. These

important structural complications, however, are often overlooked or assumed away in much of the theoretical literature associated with optimal incentive contract specification.

Incentive contract theorists have added considerable complexity to the contract specification problem in the form of motivational and informational assumptions. Enhancements to the basic model structure, as demonstrated by the original Scherer and Williamson models, are directed toward the assumed singular fee-maximizing motive of the contracting firm. It is realistic to expect that the contracting firm is motivated toward the satisfaction of a goal vector more sophisticated than the fee received on the current contract. Additional motives which are analyzed include long-term profits, staffing considerations, organizational slack, technical capability, and reputation.

Significant informational enhancements have been incorporated into the analysis of optimal incentive specification through the body of literature generally known as agency theory. Agency theory is particularly relevant to defense contracting because explicit recognition is given to the risk and uncertainty associated with advanced weapon system development and production. Expectations in the form of probability assessments of possible 'states-of-nature' (which are assumed to influence the final project outcome) from the perspective of both the DOD and the contractor are incorporated into

the analysis. In addition, consideration is given to the risk preferences of the DOD (principal) and the contracting firm (agent) via assumptions directed at the structural forms of their respective utility functions. Finally, considerations of informational availability are included in the agency model these considerations recognize the possible existence of a monitoring mechanism utilized by the principal--specifically an ability of the principal to observe the de facto state-of-nature and/or the "effort level" of the contracting firm in addition to the final outcome.

While incentive contract theorists have considered the influence several ex ante aspects of defense contractor behavior may have on optimal contract specification (e.g. 'buying into' a particular contract by submitting biased initial cost estimates), very little attention has been focused on ex post behavioral considerations of possible consequence. A notable exception is provided in agency theory with the analysis of 'moral hazard' behavior on the part of the contractor into the basic analysis. Moral hazard involves the contractor making a less than satisfactory effort (an additional element in the agent's utility function with assumed negative marginal utility) on an awarded contract and blaming the result on an unfortunate state-of-nature. The monitoring capacity of the DOD (principal) mentioned above is of course relevant to this behavioral consideration.

Various models of incentive contracting which incorporate these 'real-world' enhancements are discussed in the following section. This is followed by a review of the empirical studies of incentive contract effectiveness as applied to weapon system procurement. The chapter closes with mention made of several important investigations into extracontractual determinants of contractor performance.

2.2 Theoretical Literature Review

As previously mentioned, the following is not a comprehensive review of the many studies pertinent to incentive contract theory. The models that are discussed were chosen because they collectively demonstrate the 'real-world' sophistication which has been built into the analysis of optimal incentive contract specifications. Four theoretical models are considered: The Scherer model, the Williamson model, the principal-agent model, and the principal-agent model with moral hazard.

2.2.1 The Scherer Model[9]

The purpose of the Scherer model is to analyze the optimal choice of the sharing proportion, α, from the standpoint of both the contracting firm and the DOD. Ignoring any performance or scheduling considerations and assuming actual costs to always be less than ceiling costs, the fee received by the contracting firm may be written as

$$(3)\ F = \Pi_T + \alpha X,$$

where $X = C_T - C_A$ and $0 \leq \alpha \leq 1$. It is assumed that Π_T is a monotomically increasing (quadratic) function of α, or

$$(4)\ \Pi_T = k + h\alpha + m\alpha^2.$$

The rationale for this assumption is that the contractor bearing a greater risk of fee loss due to cost overruns should receive a higher target profit as compensation. Finally, C_T is assumed to be exogenously determined.

The simple version of the Scherer model assumes the contractor is seeking to maximize the expected value of F (i.e. risk neutrality assumed) and is aware, ex ante, of the actual cost outcome $\hat{X}$ that results. In addition, it is assumed $m = 0$ so that F is a linear function of X. The objective function of the contractor is

$$(5)\ \text{Max} \quad F = k + h\alpha + \alpha\hat{X}.$$

The first order condition ($\frac{dF}{d\alpha} = 0$) results in the optimal α being polarized between either $\alpha = 1$ (if $\hat{X} > -h$) or $\alpha = 0$ (if $\hat{X} < -h$) except in the case where $\hat{X} = -h$. In this situation ($\hat{X} = -h$), the optimal α is indeterminant.

The initial formulation of the Scherer model assumes the cost overrun or underrun is known before α is specified. Thus, any possible (inverse) relation between α and the cost outcome, $\hat{X}$, is ignored.[10] In order to include this central relationship, assumptions must be made concerning some function of X which will offset or constrain potential improvements in F due to incentives for cost reduction. The second version of the Scherer model introduces the concept of user cost, U, as a monotonically increasing quadratic function of the amount by which actual costs are reduced below target, or

$$(6)\ U = bX + cX^2.$$

The rationale for this assumption is that cost reduction on a current contract reduces future profit potential due to (among other things) negative effects on product performance quality.[11]

Relaxing the assumptions that $m = 0$ and X is known ex ante, the contractor is now faced with a 2-staged decision; determination of the optimal α and the subsequent determination of the optimal level of cost reduction efforts, X. Solving the second problem first, the contractor maximizes

$$(7) \quad F = \Pi_T + \alpha X - (bX + cX^2),$$

and the first order condition results in

$$(8) \quad X = \frac{\alpha - b}{2c}.$$[16]

Note that the optimal X has the desired relationship with α --as the sharing proportion increases, the level of cost reduction efforts increases.

Determining the optimal α, involves maximizing a somewhat different function. Substituting (6) into (7) yields

$$(9) \quad F = k + h\alpha + m\alpha^2 + \alpha X - bX - cX^2.$$

By substituting (8) and differentiating (with respect to α), we obtain as a first order condition

$$(10) \quad \alpha = \frac{b - 2ch}{1 + 4cm}.$$

The results of this version of the Scherer model show that the optimal value of α (from the perspective of the contractor) may be between 0 and 1 if the appropriate values of the parameters b, c, h, and m are chosen and X is less than 0 (i.e., in overrun situations.)

Finally, government concerns are incorporated into the model. From (2), the government is assumed to be interested in minimizin its total contract outlays,

$$G = C_T + \Pi_T - (1 - \alpha)X,$$

or substituting (4) and (8),

$$(11)\quad G = C_T + k + h\alpha + M\alpha^2 - \left(\frac{\alpha - b}{2c}\right) + \left(\frac{\alpha - b}{2c}\right).$$

By differentiating with respect to α, we obtain as a first order condition

$$(12)\quad \alpha = \frac{1 + b - 2\,ch}{2 + 4m}.$$ [18]

The final results of the expanded version of the Scherer model show that the only incentive scheme optimal to both the contractor and the DOD (i.e., when Equations (10) and (12) are equivalent) is when $\alpha = 1$. This situation occurs only in overrun situations ($X < 0$) and when appropriate values are chosen for the parameters of the user cost function and the assumed quadratic relationship between Π_T and α. Thus, conflict is expected to exist between the contractor and the DOD whenever attempts are made to negotiate an incentive-type contract.

2.2.2 The Williamson Model[13]

The purpose of the Williamson model is to analyze factors which determine contract cost performance and to suggest improvements in DOD procurement policies. The Williamson

model is similar to the model developed by Scherer in that the standard algebraic representation is initially utilized and performance, schedule and cost ceiling considerations are ignored. Williamson extends the Scherer analysis by developing a more sophisticated user cost function that explicitly includes non-direct cost elements in a multi-period framework. This allows additional 'real-world' enhancements to be included in the model.

The actual current period costs C_A incurred on a given contract are broken down into two components: the current-period direct (operating) costs C_1 and the current-period 'investments' in administrative and technical staff S_1, or

$$(13)\quad C_A = C_1 + S_1.$$

In addition, target profit Π_T is defined as the difference between target revenue R_T and target cost C_T, or

$$(14)\quad \Pi_T = R_T - C_T.$$

Defining the target rate of return over target cost ρ as

$$(15)\quad \rho = \rho(\alpha) = \frac{R_T - C_T}{C_T}$$

where $\frac{d\rho(\alpha)}{d\alpha} > 0$,[14]

the target profit may be written as

$$\Pi_T = (1 + \rho)\ (R_T - C_T),\ \text{or}$$

$$(16)\quad \Pi_T = \rho\, C_T.$$

Finally, the actual fee received by the firm on the current contract may be rewritten by substituting (13) and (16) into (2), or

$$(17)\quad F = \rho C_T + \alpha(C_T - C_1 - S_1).$$

In the Williamson model, the contractor is assumed to maximize the present value of current and future contracts. The model is extended into a multiperiod framework by defining R_2, C_2, S_2 and V as future revenues, future direct costs, future staff expenditures and the discount factor, respectively. The present value of future profits, Π_F, may thus be defined as

$$(18)\quad \Pi_F = (R_2 - C_2 - S_2)V.$$

An additional enhancement of the Williamson model is that specific attention is focused on the 'real-world' importance of contractor reputation and capability. Future revenues R_2 are assumed to be a function of the overrun allowance γ (which is an assumed increasing function of the cost variance). The rationale for this assumption is that cost overruns on contracts involving a great deal of uncertainty and risk (i.e., variance) do not damage contractor reputation (and future revenues) as much as would otherwise be the case. Defining Z_1 to be the excess of cost over the allowable overrun, the 'reputation effect' and 'capability effect', respectively, may be written as

(20) $\frac{\partial R_z}{\partial Z_1} < 0$, where $\frac{\partial^2 R_z}{\partial Z_1} < 0$

(21) $\frac{\partial R_z}{\partial S_1} > 0$ where $\frac{\partial^2 R_z}{\partial S_1} < 0$.

The final enhancement of the Williamson model requires that a minimum level of acceptable performance on each contracted project be achieved. The performance specifications on a given project, $\bar{P}$, are assumed to be attained as a function of the current period direct costs and 'investment' in staff, or

(22) $\bar{P} = f(C_1, S_1)$

where $\frac{\partial f(.)}{\partial C_1} > 0$, and $\frac{\partial f(.)}{\partial S_1} > 0$.

The objective function of the contractor may now be written in the form of a constrained optimization problem using (17), (18) and (22), or

(23) $\max F(C_1, S_1, \lambda) = p(\alpha)\, C_T + \alpha(C_T - C_1 - S_1)$

$+ (R_2 - C_2 - S_2)\, V + \lambda(f(C_1, S_1) - \bar{P})$.

The first order condition results in a MRTS between direct costs and staff "investment" expenditures of

$$(24) \quad -\frac{ds_1}{dC_1} = \frac{\frac{\partial f(.)}{\partial C_1}}{\frac{\partial f(.)}{\partial S_1}} = \frac{-\alpha + \frac{\partial R_2}{\partial Z_1} V}{-\alpha + \left(\frac{\partial R_2}{\partial S_1} + \frac{\partial R_2}{\partial Z_1}\right) V}$$

which is plotted in Exhibit 2.1.

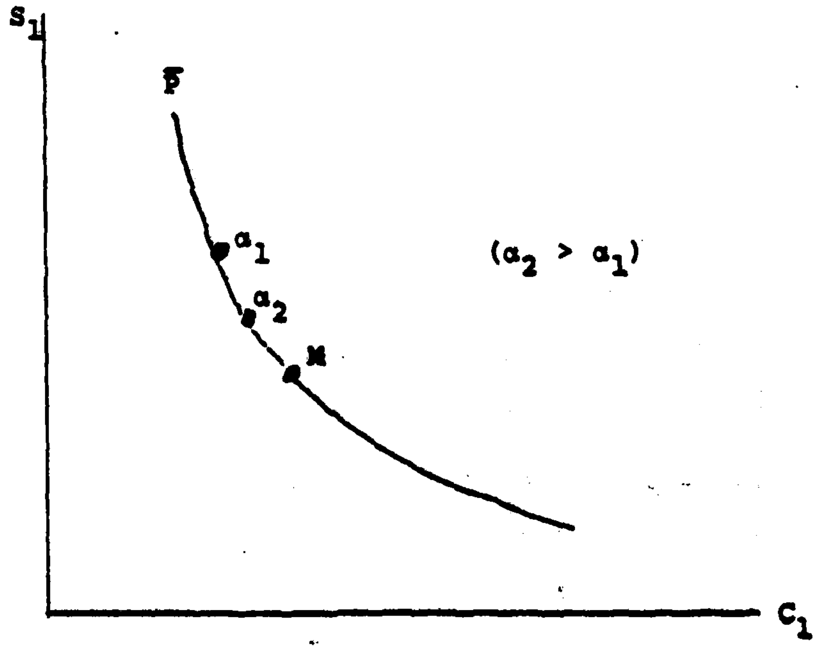

Exhibit 2.1.

Due to the required performance specification, the contractor is constrained to operate along the P locus, minimized at point M. However, because the absolute value of the denominator in Equation (24) is smaller than the numerator (due to the capability effect, $\frac{\partial R_2}{\partial S_1}$), the contractor always chooses a (S_1,C_1) pair to the left of M (i.e., the MRTS > 1). The contractor desires to over-invest in staff due to the favorable effect it has on future revenues R_2.

We are now in a position to analyze the effect of increasing the sharing proportion on the contractor optimal choice of a (S_1,C_1) pair. Differentiating (24) with respect to α and holding C_T constant (see Eq. 19) results in a decrease in the MRTS--i.e., movement toward M. This implies that as the sharing proportion is increased from α_1 to α_2 (see Exhibit 2.1) the contractor substitutes direct costs for staff "investment" expenditures.

It is important to note that the desired directional-response between α and S_1 requires that target costs C_T be invariant with changes in α (i.e., $\frac{\partial C_T}{\partial \alpha} = 0$). If C_T increases with increases in α the effect on the MRTS is ambiguous due to the possible suppression of the reputation effect, $\frac{\partial R_2}{\partial Z_1}$. However, provided that a meaningful reputation effect is enforced, differentiating (24) with respect to C_T demonstrates an unambiguous positive relationship

between C_T and the MRTS. In other words, negotiating lower target costs necessarily results in lower 'investment' in staff. An expanded version of the Williamson model demonstrates that these general properties hold true when the contractor maximizes a utility function which includes staff and operating slack as well as long-run profits.[15]

Thus, the results of the Williamson model demonstrate that the sharing proportion α cannot be an effective incentive device without regard for the negotiated target cost C_T. Furthermore, attempts to improve procurement policy (through either α or C_T manipulation) requires effective reputation effect evaluations.

2.2.3 The Principal-Agent Model[16]

The principal-agent model, commonly known as agency theory, is concerned with developing a general incentive framework that characterizes Pareto Efficient fee schedules given knowledge of the preferences and beliefs of the principal (DOD) and the agent (contractor). A fee schedule is defined as Pareto Efficient (PE) if the expected utilities of the principal and agent which result from the (fee induced) actions of the agent are not Pareto dominated by another fee schedule. As shall be seen, only under very restricted conditions is the resultant PE fee schedule applicable to DOD contractual arrangements.

In order to discuss the principal-agent relationship in a decision-theoretic context, it is necessary that all aspects of the decision environment be explicitly specified. This requires knowledge of the available information, preferences and expectations of the principal and the agent, the set of feasible technical choices available to the agent, the agent's fee to act mapping and, finally, the consequences or outcomes of these actions. Some additional notation is necessary:

$U(.)$	- the principal's N-M utility function over monetary rewards[17]
$V(.)$	- the agent's N-M utility function over monetary rewards
$a \epsilon A$	- the agent's actions chosen from the set of feasible actions
	- the random state-of-nature
$h_a(\theta), h_p(\theta)$	- the probability assessments of the agent and principal, respectively
$x = X(a, \theta)$	- the payoff (outcome) function
$f = f(X, a, \theta)$	- the fee schedule where the elements (a, θ) define the principal's monitoring capacity[18]
a(<f>)	- the agent's fee to act mapping given a fee schedule <f>.

Assume for the remainder of this section that the principal and agent share the same probability assessment of all possible states (i.e., $h_a(\theta) = h_p(\theta)$) and the fee schedule is a function of the outcome only (i.e., $f = f(x)$).The agent's

problem involves the choice of an optimal act conditional on a given fee schedule, or

$$(24)\quad \max_{a\epsilon A} \quad \sum_{\theta} V\{f(x(a,\theta))\}.h_a(\theta).$$

The principal's problem is to choose a fee schedule which motivates the agent to act in a fashion which maximizes the principal's residual payoff, or

$$(25)\quad \max_{<f>} \sum_{\theta} \quad U\{x-f(x(a,\theta))\}.h_p(\theta),$$
$$\text{s.t.}\quad E(V) \geq k.$$

The rationale for the constraint is that terms of the fee schedule as specified by the principal must provide the agent with a minimum level of expected utility or the agent would not enter into a contractual arrangement.

Ignoring for the moment any Pareto considerations, the problem as specified involves the principal motivating the agent by solving (24) for <f> subject to the $E(V) \geq k$ constraint. This, of course, requires that the principal possess complete knowledge of the payoff function, $X(a, \theta)$, as well as complete information concerning the agent's fee to act mapping, $a(<f>)$.[19] Aside from the exorbitant demands these assumptions place on the cognizance of the principal, a major deficiency of this solution centers on the resultant fee schedule being dependent on a particular decision situation and its associated payoff (outcome)

function. If the work to be performed by the agent involves multiple decisions (i.e., multiple outcome functions), each problem would require a separate fee schedule. Decisions could not be decentralized and, as noted by Wilson, computation cost no longer ignored.[20] Therefore, we want to constrain consideration of possible optimal fee schedules to include only those which may be specified independent of $X(a,\theta)$.

Ross has provided a very elegant solution to this problem in one particular case utilizing the principal of similarity.[21] Assuming the principal and agent have identical assessments of future states $(h_p(\theta)) = h_a(\theta))$ and possess utility functions belonging to the same one of three possible 'conformable' types, then the PE fee schedule is linear.[22] Linear fee schedules, in general, may be written as

$$(26) \quad f(X) = \alpha x + \beta,$$

and reinterpreted as Eq. (1) where $x = -C_A$ and $\beta = \Pi_T + \alpha C_T$. An additional result associated with the PE linear fee schedule solution is that the principal and the agent have identical preferences toward risk. This is significant in that the expected utility of the principal is automatically maximized by the agent's choice of an action, $a \epsilon A$, regardless of the decision situation. In other words, decisions can be decentralized because the agent behaves in a manner consistent with the desires of the principal without the need for new fee schedules as the decision situation changes. Finally,

note that the optimal fee schedule, $f(X)$, is a function only of the outcome, X (which depends indirectly on θ), and does not require the principal to directly observe a or θ. However, PE considerations require that the risk be shared (i.e., $\alpha > 0$) due to the indirect effect of θ on f through X.[23]

Thus, under special circumstances, the principal-agent model is shown to yield a set of solutions applicable to the defense contracting problem. It is important to recognize, however, that decentralization of multiple decisions (as is obviously required) is possible only when linear PE fee schedules are permitted.[24] This in turn is dependent on (among other things) strong assumptions concerning identical probability assessments over all θ and equivalence of utility functions (i.e. risk preferences) for the principal and the agent. If these assumptions are violated, PE fee schedules are possible but are not invariant from one decision situation to the next. Despite the significance of this shortcoming, these assumptions are relaxed in the next subsection in order to investigate the inclusion of important behavioral considerations into the principal-agent relationship.

2.2.4 The Principal-Agent Model with Moral Hazard[25]

The basic principal-agent model introduced in the previous subsection has been extended to include a variety of different situations within which the agency relationship

may exist. For example, the principal and the agent may possess different preferences toward risk, and/or the fee schedule may be dependent on additional information as well as the final outcome. Of particular interest is the added realism which results when nonpecuniary factors are included in the agent's utility function. In this subsection, we assume that the agent's utility depends on his action, $a \in A$, as well as his monetary reward m.[26] In this context, the agent's set of feasible actions, A, may be interpreted as potential levels of effort (assumed continuous) whereas earlier it may have been, for example, a finite number of research strategies.

The agent's utility function is now defined as V(m,a) where

$$\frac{\partial V(.)}{\partial m} > 0, \ \frac{\partial^2 V(.)}{\partial m^2} \leq 0, \text{ and } \frac{\partial V(.)}{\partial a} < 0.$$

In other words, the agent prefers less effort to more effort and is not a risk taker. It is further assumed that for any given state-of-nature, θ, $\frac{\partial X(\theta,a)}{\partial a} > 0$; meaning that additional effort always has a positive effect on output. Note that an unsatisfactory outcome may be the result of an unfortunate state, θ, or an insufficient level of effort expended by the agent, a. If the principal is able to monitor only the outcome, the agent is in a position to falsely claim that poor performance is the result of an uncontrollable state-of-nature regardless of his effort level. The implications of

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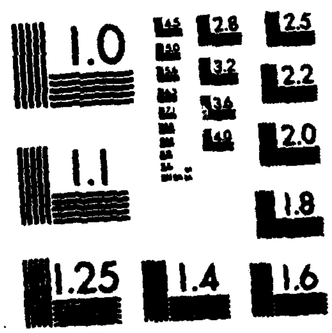

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this type of behavior, known as moral hazard, on the specification of the optimal fee schedule have been shown to depend on the risk preferences of the principal and agent and the available monitoring technology.[27]

Assume, as in the previous subsection, that the principal and agent have identical probability assessments of possible states (i.e., $h_a(\theta) = h_p(\theta)$). Harris and Raviv have shown that a fee schedule not depending on effort is Pareto-dominated by a fee schedule depending on the outcome and effort (i.e., information on the agent's effort is useful) except in two particular cases.[28] The first case occurs when the agent is risk neutral (i.e., $\partial^2 V(.)/\partial_m 2 = 0$). In this case, optimal fee schedule depends only on the outcome and Pareto-dominates any fee schedule dependent on outcome and effort. Ross has characterized the agent's fee schedule in this situation as simply the outcome (X) less a constant share for the principal.[29] The second case occurs when the principal can observe the state-of-nature as well as the outcome. Again, a fee schedule comprised of these components (X and θ) is shown to Pareto-dominate a fee schedule dependent on X and a.

The principal-agent model introduced and discussed in the previous two subsections, although extremely abbreviated, has introduced several important 'real-world' enhancements into the incentive contracting environment. Of particular

interest is the influence risk preferences, expectations, monitoring capacity, and moral hazard behavior were shown to have on the optimal specification of the contractual parameters (i.e., fee schedule).

2.3 Research Findings

The purpose of this section is to review several studies which attempt to empirically identify the major determinants of contractor performance on DOD contracts. Specifically the intent is to analyze the possible influence incentive-type contracts have had on improving the efficiency of advanced weapon system procurement. This requires, among other things, estimating the statistical correlation between the sharing proportion α and important project performance indicators. Unfortunately, several subtle difficulties inhibit the straight-forward identification and measurement of possible relationships.[31] An immediate concern involves quantifying relevant performance indicators. As previously discussed, potential contracting goals may include cost considerations--e.g. cost overruns and/or total government outlays--as well as non-pecuniary factors--e.g. weapon system performance capabilities and/or scheduling considerations. In addition, it is important to recognize that performance outcomes may be partially explained by the type of work being performed and possible exogenous differences among contracting firms. Finally, in order to isolate the effect incentives may have on various performance indicators, consideration must be given to possible ex ante and ex post modifications to other contractual parameters.

2.3.1 Contractual Incentives As Performance Motivators

In 1965 former Secretary of Defense Robert McNamera claimed in testimony before a Congressional committee that the introduction of incentives in defense contracts resulted in at least a 10% reduction in total cost relative to cost-plus contracts.[31] This is a very difficult claim to substantiate despite several empirical studies (discussed below) which suggest a possible relationship between incentive type contracts and improved cost performance. As shall be seen, an observed inverse relationship between the sharing proportion and cost performance is a necessary but an insufficient condition for establishing the effectiveness of incentive contracting.

Fisher, in a study of 948 Air Force contracts greater than $1 million, found that the average cost overrun (C_A - C_T) is significantly smaller for incentive type contracts relative to cost-plus contracts.[32] It was demonstrated, however, that the observed relationship could be the result of induced production efficiencies (i.e. decreases in C_A) or the result of increases in the negotiated target cost, C_T. If C_T is in fact invariant, Fisher suggests that an inverse relationship between the magnitude of the share and cost overruns segregated by incentive contract type (e.g. CFIF or FPI) should be observed. Fisher tests this hypothesis using several statistical formulations of the share/cost outcome relationship but the results are generally weak. The sharing proportion is shown to explain less than 10% of the variation in cost

overruns and is not statistically significant at the .05 level. Furthermore, one specification results in a statistically significant positive correlation between the share and cost overruns.

Fisher then tests to determine whether a relationship can be identified between the size of the share and the ex post changes in C_T - i.e. contract renegotiations. Again the results are weak with less than 10% of the variance in contract modifications explained with no statistical significance (.05 level). Finally Fisher examines the possible relationship between specific firms and cost outcomes, and concludes that a statistically significant relationship exists between firms. However, no statistically significant relationship is found between the size of sharing proportion and cost outcomes within firms. Fisher concludes that little evidence exists to support the contention that differences in cost overruns are explained by the incentive structure and any observed 'improvements' are probably due to ex ante increases in C_T.

Cross is also interested in investigating the effectiveness of contractual incentives in influencing cost performance. Eight verbal arguments supporting an inverse relationship between the share and cost overruns (and a direct relationship between α and overruns) are provided. Two additional arguments suggest a possible inverse relationship

between the share and the cost underrun. Therefore, because the response to changes in the share may possibly be different depending on the cost overrun/underrun situation, the data is segregated into these two categories for analysis.

In the case of overruns, a statistically significant inverse relationship is observed between the share and the cost overruns, but only after one contract with a very large cost overrun is dropped from the sample.[34] In the case of underruns, an inverse relationship is observed; implying that as the sharing rate is increased, the extent of underruns is decreased. However, this result is discounted due to the lack of significance at the .05 level. Cross concludes that evidence supporting a relationship between the sharing proportion and cost outcome is very weak. This contention is further supported in that only two of the 10 arguments which suggest a relationship exists are of any economic benefit.[35] Cross, like Fisher, concludes that any possible correlation between incentives and cost performance can be easily attributed to inflated values of C_T.

The findings of Fisher and Cross---although both explicitly discount the economic significance of observed differences in incentive and cost-plus contracts with respect to cost overruns---are not in agreement with many studies which fail to observe any relationshp between cost performance and contract-type or magnitude of the sharing proportion. Studies using a variety of samples which fail to correlate variations in incentive structures (i.e. contract types)

with project outcomes include Jones, Boyett and Strayer, Scherer, Ehnert and Kaiser, the Logistics Management Institute, Hunt and Beldon.[36]

In the sutdy of 834 contracts by Beldon, no statistically significant relationship between the magnitude of the sharing proportion and the cost overrun/underrun situation is observed.[37] This agrees with Fisher's earlier findings and is further supported by Dixon, Deavers, and McCall.[38] Beldon observes a significant correlation between the type of work being performed and the cost performance where R&D has greater overruns than production contracts. Also significantly higher profit rates ('going in' and coming out) are observed for incentive-type contracts. Contrary to Fisher and Cross, Beldon is unable to conclude that a relationship exists between incentives and C_T changes.[39]

In a study similar to Beldon's using an expanded sample (2,683 contracts), Parker identifies a <u>positive</u> relationship between incentive contracts and cost-overruns contrary to Fisher's observation. Consistent witn Beldon's findings, Parker does observe a correlation between type of work (R&D vs Production) and the cost outcome. However, Parker's results show that overruns tend to <u>increase</u> as the sharing proportion increases.[41] As in the Beldon study, Parker finds higher profit rates associated with incentive-type contracts relative to cost-plus contracts and R&D contracts relative to production contracts.

Finally, a larger volume of contract changes are observed for cost-plus contracts (as well as R&D work). This discovery is not in agreement with McCall and Fox who observe a positive relationship between incentives and negotiated cost adjustment.[43]

Thus far the review has focused on possible statistical relationships between the sharing proportion and cost overruns, profits, and target costs. Hiller and Tollison in a composite study have attempted to determine the combined effect these factors have had on total government outlays.[44] Basically, this study, relying on the available empirical literature, derives estimates (or upper and lower boundaries) for the sharing proportion, profit rates, target costs, and actual costs to the firm under incentive contracts relative to cost-plus contracts. Even in the most conservative cases with assumed improvements in efficiency (decreases in C_A) and no changes in C_T, the results are much less favorable towards incentives than those claimed by McNamera. Furthermore, if C_T is realistically allowed upward adjustment (ex ante or ex post) it is demonstrated that total costs to the government may actually increase when incentive contracts are utilized. This possibility is given further support when consideration is given to non-pecuinary incentives often included in incentive type contracts.[45] Numerous studies, including Parker, Ehnert and Kaiser, Hunt, LMI, Beldon,

and Peck and Scherer have shown that performance incentives are typically earned regardless of cost outcomes, thus further increasing the final costs to the government when incentives are utilized.[46]

To briefly summarize, investigations attempting to explain the variance in performance outcomes with contract related factors have not been conclusive. Very little evidence has been found which suggests that incentives have resulted in improved contractor efficiency, performance, or lower government costs. The economic significance of observed relationships between incentive contracts and cost outcomes by Fisher and Cross, in addition to being disputed by Beldon and Parker (among others), is tarnished by a consensus inability to statistically correlate the magnitude of the share with cost performance -- either within contract type or firm. Evidence suggesting upward adjustments in C_T in response to incentives is somewhat ambiguous although strongly suspected by many researchers (including Fisher and Cross.) Attempts to explain cost performance by the type of work being performed have also been ambiguous. A definite relationship is observed, however, between specific firms and performance outcomes. Finally, performance incentives are shown to be earned regardless of the cost outcome. The following subsection provides a partial explanation for the apparent ineffectiveness of contractual incentives by

focusing on research into extra-contractual determinants of contractor performance.

2.3.2 Extra-Contractual Influences and Related Considerations

The empirical results reviewed in the previous subsection are difficult to characterize beyond the obvious conclusion that incentives do not dominate or predictably influence the attainment of contract performance outcomes. Before discussing several possible explanations for this apparent failure it is helpful to identify factors which are thought to influence performance from the perspective of defense contractor management and technical personnel. An investigation into this question, as part of a larger NASA-funded study (discussed below), was conducted by Hunt, Near, and Rubin via questionnaires completed by individuals within various defense contractor organizations.[47] The 829 respondents rank-ordered 10 items which are thought to affect contractor performance on R&D contracts. Of the three items categorized as inconsequential, two are specifically related to the contract itself: contractual possibilities for profit (the weakest of the 10 influences) and the nature of the procurement. The three determinants considered most influential by contractor personnel contain no contractual considerations: the prospects for follow-on work, the work plan, and the clarity of the job specifications.

Thus, the required causal linkage between profit-making opportunity and performance underlying incentive contract theory seems to be at odds with determinants of performance as perceived by actual defense contractors. The remainder of this subsection attempts to explain this divergence by focusing on three potential influences not adequately addressed by theoretical models of incentive contracting: motivational influences, organizational influences, and environmental influences.

Motivational Influences

In order to establish the motivational status of a potential incentive, it is necessary to demonstrate that its presence satisfies an essential need or goal of the recipient. In a study of 27 aerospace/electronics defense contractors by Rubin and Hunt, 221 managerial respondents rated 19 organizational goals in terms of importance.[48] The results were categorized into five general corporate objectives with the following results, in order of importance: 1) sustained position in government markets, 2) overall efficiency, 3) company growth, 4) short-run profitability, and 5) citizenship. Contractor respondents also revealed the following goals with respect to the negotiation of individual DOD contracts:

1. Foster quality performance
2. Protect the contractor against risk
3. Safeguard proprietary interests
4. Offer operational flexibility
5. Stimulate high levels of contractor/government interaction
6. Engender high degrees of motivation to control costs
7. Yield a high profit level
8. Reduce government technical direction or surveillance, and
9. Foster program discipline.

In an expanded study by Hunt et. al., 841 defense contractor respondents rated the importance of 40 items in terms of their influence upon operational decision-making within their respective companies.[49] The results again demonstrate the influence goals other than profit--including, for e.g., safety (risk-adversion), image making, growth, survival, reputation, and effective performance -- have on decision-makers in defense contracting organizations. Finally, an investigation, cited in the larger NASA-funded study, into the motives and rewards for entering and remaining in the defense contracting business corresponds closely with the goals mentioned above, with one notable exception -- the valuable support DOD business provides for the development of commercial products (i.e., technology transfer).[50]

It is apparent that defense contractors are concerned with many factors in addition to profit when defining overall corporate strategy as well as when negotiating contracts and making operational decisions. The motivational status of profit is further tarnished by an often observed tendency for contractors to establish voluntary upper limits on the level of acceptable profit allowed on a given contract due to possible negative effects DOD (or congressional) scrutiny may have on future contract negotiations (e.g., Williamson, Scherer, LMI).[51] A number of independent studies lend support to the possible dominance of non-contractual goals in influencing contractor behavior (e.g., Booz, Allen and Hamilton, Cummins, Oppendahl).[52]

Fox attributes the apparent failure of short-run profit incentives to motivate defense contractors to (among other things) their persistence in negotiating 'follow-on' contracts -- i.e., maintaining a share of the DOD market by the continued submission of proposals describing new projects or suggested enhancements to existing projects.[53] A Logistics Management Institute (LMI) study concludes that contractors seldom sacrifice performance attainment for short-run profit due to the possible effect on company image.[54] Similarly, Lynch and Pace suggest that defense contractors attempt to foster long-term growth by "maintaining a competitive position" capable of winning future

contracts.[55] This, according to Lynch and Pace, requires retaining high quality technical and supervisory staff -- even in periods of declining business activity -- and often results in overbilling a given contract (i.e., cost overruns) and sacrificing short-run profit potential.

Thus, defense contracting organizations are shown to have organizational goals which may not be in agreement with the attainment of short-run profits. Contractual incentives singularly based on this motive are effective only to the extent contracting organizations make the appropriate tradeoffs among conflicting goals. Discussing the defense contractor's long-term profit goal, Scherer notes that:

> ". . . there is typically a conflict in development program tradeoff decisions between the short-run accounting profits obtained by minimizing R&D contract costs and the longer-run profits attainable by securing follow-on production contracts and maintaining a reputation for high quality and timely performance."[56]

Organizational Influences

In order for an externally applied incentive system to be operative with respect to defense contracting organizations, either the incentives must appeal directly (or be effectively transmitted) to the appropriate decision-makers, or the organization must be structured so that incentive recipients are able to adequately influence the organizational decision process as it affects performance outcomes. Studies

of defense contractor organizational structure and behavior discussed below analyze these considerations and reveal several important extra-contractual influences on performance.

The contractor decision-making process with respect to individual contracts necessarily requires a certain degree of decentralization due to the specialized demands of high-technology product development. Lynch and Pace, in their detailed study of overhead cost control in defense contractor organizations, find decision responsibility very difficult to track as decisions are frequently made by managers "scattered" throughout the organization.[57] Similarly, Hunt, Near, and Rubin observe decision-making in contractor organizations to be "somewhat disorderly" and "unintegrated."[58]

Consistent with these findings, the study by LMI concludes that a major shortcoming of incentive contract application results from an inability "to pass incentive motivation to the people who carry out the contract effort."[59] Hill and Shepard in a study of contractor organizations also report that incentives are not passed down to lower organizational levels.[60] More importantly, it is not altogether clear that profit-based incentives would be effective in influencing the relevant decision-makers. As demonstrated

by the results of Hunt, et. al., the individual goal structures of defense contractor technical and managerial personnel are dominated by personal concern for safety, responsibility, esteem, autonomy and other intrinsic factors.[61] Finally, the detailed investigation of three contracting organizations by Hill and Shepard report observing no organizational changes in product treatment precipitated by incentive contracts vis-a-vis other contract types--i.e., all projects are treated in a similar administrative manner with no attempt to maximize profit potential via program decision tradeoffs.[62] This conclusion is further substantiated by Hunt, Rubin, and Perry, who find that two-thirds of the 27 contractor organizations studied do not adjust to organizational procedures to maximize incentive gain.[63]

Thus, defense contracting organizations (out of necessity) are shown to be relatively decentralized with the decision-making process and relevant decision-makers unamenable to effective motivation by contractual profit incentives. While these organizational considerations are clearly important, additional insights into extra-contractual determinants of performance are gained by examination of the general environment in which decisions affecting performance outcome are made.

Environmental Influences

A recent model of the defense procurement process developed

by Cummins suggests that poor performance observed on defense contracts are a natural consequence of the defense contracting environment.[64] It is hypothesized that a substantial portion of cost overruns may be explained by three exogenous factors: the contractor's degree of risk adversion, extent of moral hazard, and bargaining strength. Although empirical tests by Cummins of 45 FPI and 26 CPIF contracts fail to conclusively validate the model's specification, several formulations of the reduced form regression equation suggest that the model's overall explanatory power is not inconsequential.[65] In order to reduce the level of inconclusiveness concerning the effect non-contractual environmental factors may have on project outcomes, Cummins suggests the need for an extension of "the economist's existing knowledge of the working of a large diversified corporation . . . [and] the incorporation of dynamic aspects . . . into the decision-making framework of the theoretical model.[66] The recommendations are considered necessary due to the recognized significance (on performance outcome) of organizaticnal decisions made during the considerable time lapse between the negotiation and completion of a given contract.

The results of a study concerned with environmental constraints on project performance as perceived by contractor personnel by Hunt, Near, and Rubin reinforces the importance of the managerial decision process.[67] Of 841 respon-

dents, 86.2% felt project outcome were determined by "operational decisions made along the way." Furthermore, a majority felt that operational decisions were made with "a good deal of latitude" and based on "considerations other than contractual." Finally, a large majority (80.1%) felt that how a given project turns out depends "almost entirely on the contractor's own capabilities" rather than on factors external to their control. In the final report of the NASA-funded study, Hunt concurs with the recommendations made by Cummins concerning the importance of the manager's decision process environment. Hunt concludes that "studies of concrete decision processes" of contractor organizations are necessary in order to more fully understand their "operational motivation" and "actual conduct."[68]

Finally an obvious, but nonetheless significant, environmental consideration which may directly influence performance outcomes is the organizational interaction of the DOD with the contracting firm. Runkle and Schmidt have demonstrated that DOD/contractor interaction may be a useful mechanism in which to focus managerial attention on project performance.[69] In a study of 56 contracts, a significant relationship is observed between higher performance ratings and "influential" organizational interaction - defined as a function of the frequency and the hierarchial level of the organizational interaction. Specifically, if organizational interaction occurs at high management levels (or more frequently), the

'pressure' or communication relaying DOD project concerns is shown to be more effective than if the interaction occurs at lower levels (or less frequently). Implicit, of course, in this potentially controllable environmental influence on contractor performance is a monitoring capacity which allows the DOD to identify possible project deficiencies before final contract completion.

2.4 Conclusion

This chapter has provided a general overview of the theoretical foundations of incentive contracting and reviewed a number of investigations into the contractual and extra-contractual determinants of contractor behavior. Notwithtanding the analysis of several 'real world' considerations, important factors nave been identifiea whicn significantly influence performance outcomes but are naively ignored (or assumed away for computational simplicity) in the theoretical models of Section 2.2. It is suggested that until a more sophisticated theoretical framework is utilized which envelops the dominant performance determinants as identified in Section 2.3, analyses of defense contractor behavior will be notably deficient.

To briefly summarize, the perceived failure of incentives to influence contract outcomes to a large extent results from the unrecognized importance of extra-contractual factors in determining defense contractor behavior. Extra-contractual influences which have been verified as consequential include:

1) The motivational importance of goals other than short-run profit (including risk avoidance) to managerial, administrative, and technical personnel within the contracting firm,

2) The conflicting nature of the multiple goals and the necessary tradeoffs required during the operational decision-making process,

3) The decentralized structure of decision-making within contractor firms with multiple decision makers operating at various organizational levels,

4) The organizational interaction of the DOD with the contracting firm at different levels in the management hierarchy, and

5) The dynamic aspects of multiple decisions associated with a given project which are made after initial contract negotiation but prior to the determination of performance outcome.

It is evident that the incentive models discussed in Section 2.2 do not give adequate attention to how decisions are actually made in defense contracting organizations. None of the models consider, for example, the dynamic organizational environment in which multiple decisions relevant to individual projects are simultaneously made (or influenced) by various decision makers (or circumstances) who are possibly pursuing conflicting operational objectives. The demonstrated importance of the extra-contractual factors listed above suggest that the external market environment does not dominate the contractor's economic behavior and explicit consideration must be given to the internal operation of the firm. In

other words, the qualitative properties (and predictions) associated with the general incentive models previously discussed must be replaced with a more sophisticated model which recognizes the actual operating environment, behavior and decision processes of the organizational decision-making units. Such a theoretical perspective of the business firm, as described in the subsequent chapters, is provided by the body of literature commonly associated with the behavioral theory of the firm.

Footnotes - Chapter 2

[1]See A. M. Agapos and Paul R. Dunlop, "The Theory of Price Determination in Government Industry Relations", Quarterly Journal of Economics (February, 1970), pp. 85-99, for a characterization of the government bargaining relationship when dealing with a single firm as opposed to multiple firms.

[2]This notation follows closely that utilized by Frederic M. Scherer, The Weapons Acquisition Process: Economic Incentives, (Boston: Harvard University Press, 1964), pp. 412-431, and many other models of incentive contracting noted below.

[3]Technically, as mentioned in Chapter 1, a cost ceiling is applicable only to FPI contracts. Therefore, we would need to ignore Cc in order to formally describe CPFF and FFP contracts.

[4]This is a misnomer in that the implication is made a contract with $0<\alpha<1$ offers greater 'incentives' than a FFP ($\alpha=1$) contract. Of course, this is not necessarily true. See ibid, p. 135.

[5]This in fact is the general conclusion of an empirical study, discussed below, by John R. Hiller and Robert O. Tollison, "Incentive Versus Cost-Plus Contracts in Defense Procurement," Journal of Industrial Economics, 26 (March 1978): 239-248.

[6]See John M. Parker, Jr., "An Examination of Recent Defense Contract Outcomes in the Incentive Environment," (Master's Thesis, Air Force Institute of Technology, 1971) for discussion and attempted estimation of the relationships among various contractual parameters by contract type, ex ante and ex post.

[7]Scherer, op. cit., pp. 412-431; and Oliver E. Williamson, "The Economics of Defense Contracting: Incentives and Performance," in Issues in Defense Economics, ed. Roland N. McKean (New York: Columbia University Press, 1967), pp. 217-56.

[8]See J. J. McCall, "The Simple Economics of Incentive Contracting," American Economic Review, 60 (December 1970):

pp. 837-46, for a discussion and analysis of the economic motivation of deliberate biased cost estimation by potential contractors.

[9] Scherer, op. cit., pp. 412-431.

[10] This precluded relationship is the foundation of the reward theory incentive for cost improvements--i.e., we would hopefully expect X to depend somewhat on α.

[11] See ibid, pp. 407-411, for an extended discussion of user cost functional forms and justification.

[12] The second order condition of Equations (8), (10) and (12) are shown to be satisfied given proper values of the parameters.

[13] Williamson, op. cit., pp. 217-56.

[14] The second order condition ($\partial^2 P/\partial p^2 < 0$) is assumed to be satisfied. This relationship is very important as it serves the same purpose as Equation (4) in the Scherer formulation--linking Π_T to α ex ante.

[15] See Oliver E. Williamson, Defense Contracts: An Analysis of Adaptive Response (Santa Monica: Rand Corporation Memorandum, 1965).

[16] In addition to specific references noted below, general background for the standard principal-agent problem is found in L. Peter Jennergren, "On the Design of Incentives in Business Firms - A Survey of Some Research," Management Science, Vol. 26, no. 2 (February 1980): 180-201; Marvin Berhold, "A Theory of Linear Profit-Sharing Incentives," Quarterly Journal of Economics, 85 (1975): 207-232; Stephen A. Ross, "The Economic Theory of Agency: The Principal's Problem", American Economic Review, Proceedings issue, 63 (1973): 134-139.

[17] Both $U(\cdot)$ and $V(\cdot)$ are usually assumed to be monotone increasing and quasi-concave (i.e., risk preferring behavior is not considered).

[18] The principal is assumed to have knowledge of X in all cases, but information on a and θ may be incomplete. The fee schedule may, of course, include only those elements known by the principal.

[19] See Ross, op. cit., pp. 134-135.

[20] R. B. Wilson, "On the Theory of Syndicates," Econometrica, 36 (1968): 119-132.

[21] Stephen A. Ross, "On the Economic Theory of Agency and the Principal of Similarity," in Essays on Economic Behavior under Uncertainty, eds. M. Balch, D. McFadden, and S. Wu (Amsterdam: North Holland, 1974), pp. 215-237.

[22] The types are: power function utilities with the same power, exponential utilities or logarithmic utilities. Ross, op. cit., p. 224.

[23] See Ross, op. cit., p. 221.

[24] As noted in R. B. Wilson, "The Structure of Incentives for Decentralization under Uncertainty," in La Decision, ed. M. Gilband (Paris: Centre Nationale de la Recherche Scientifique, 1969), pp. 293-295.

[25] In addition to specific references noted below, background for this section is found in Jennergren, op. cit.; Joel Demski and Gerald A. Feltham, "Economic Incentives in Budgetary Control Systems," Accounting Review, 53 (1978): 336-359; Milton Harris and Artur Raviv, "Optimal Incentive Contracts with Imperfect Information," Journal of Economic Theory, 20 (1975): 231-259; Stephen Shavell, "Risk Sharing and Incentives in the Principal and Agent Relationship, Bell Journal of Economics, 10 (1979): 55-73.

[26] For analysis of other nonpecuniary factors besides effort level (or action) within the agent's utility function, see Michael C. Jensen and William H. Meckling, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure," Journal of Financial Economics, 3 (1976): 305-306.

[27] Milton Harris and Arthur Raviv, "Some Results on Incentive Contracts with Applications to Education and Employment, Health Insurance, and Law Enforcement," American Economic Review, 68 (1978): 20-30.

[28] Idem, "Optimal Incentive Contracts with Imperfect Information," pp. 239-247.

[29] Shavell, op. cit., p. 59.

[30] See Kenneth M. Graver and Jerold L. Zimmerman, "An Empirical Study of USAF FPI and CPIF Contracts," Research paper presneted under Contract No. F33615-76-C-5371 (Wright-Patterson AFB, Ohio: Air Force Business Research Management Center, 1976) for a thorough discussion of the many data problems inherent in the empirical analysis of incentive type contracts.

[31] Robert McNamera, Testimony before Joint Economic Committee on the Economic Impact of Federal Procurement (Washington: U.S. Government Printing Office, 1969).

[32] I. N. Fisher, A Reappraisal of Incentive Contracting Experience (Santa Monica: Rand Corporation Memorandum, July 1968). It should be mentioned that in a subsequent report, "An Evaluation of Incentive Contracting Experience," Naval Research Logistics Quarterly, 16 (March, 1969): 63-83, Fisher reached somewhat different conclusions in that no correlation between cost overruns and contract type were observed. The 1968 study consisted of Air Force contracts between the years 1956 and 1966, greater than $1 million.

[33] John G. Cross, "A Reappraisal of Cost Incentives in Defense Contracts," Western Economic Journal (June, 1968),

[34] In fact, inclusion of this observation reversed the sign, op. cit., pp. 221. Only 43 FPIF contracts were included in the sample in which the overrun relationship was observed.

[35] For example, possible explanations by Cross which suggest a tendency for high sharing proportions to be associated with smaller overruns include: (1) It is easier to induce firms to accept high sharing rates in less risky contracts, (2) If firms do accept high risk in contracts, they will tend to charge for it by increasing C_T and reducing overruns, (3) High sharing rates given contractors incentive to put all possible cost increases into the "adjusted cost" category, rather than permitting them to result in overruns, (4) Relatively inefficient contractors would be most willing to make low bids on contracts with low cost sharing ratios and increases in α would result in the most efficient contractors receiving the award, op. cit., pp. 220-221. Note that only the better explanation is of economic significance.

[36] Troy H. Jones, "A Study of Related Aspects of the Use of Incentive Contracts in USAF Procurement Management," (Ph.D.

Dissertation, Ohio State University, 1967); J. E. Boyett and D. E. Strayer, "Analysis of Cost and Non-Cost Negotiated Profit Factors in Department of Defense Contracting," Report to the OASD (I&L) Profit '76 Study by the Air Force Business Research Management Center and the Air Force Institute of Technology (1976); Frederic M. Scherer, "The Theory of Contractual Incentives for Efficiency," Quarterly Journal of Economics (May, 1964) 78: 257-80; George C. Ehnert and Donald W. Kaiser, "Civil Engineering Service Contracts: Relationship of Performance to Contract Type," (Master's Thesis, Air Force Institute of Technology, 1976); Logistics Management Institute, An Examination of the Foundation of Incentive Contracting, LMI Task 66-7 (Washington, D. C.: LMI, 1968); Raymond G. Hunt, "Extra-Contractual Influences in Government Contracting," A formal study for NASA under Grant No. NGR 33-015-061, conducted by the Survey Research Center, State University of New York (1971); David L. Belden, "Defense Procurement Outcomes in the Incentive Contract Environment," (Ph.D. Dissertation, Stanford University, 1969).

[37] Belden, op. cit., p. 96.

[38] M. Dixon, "A Statistical Analysis of Deviations from Target Cost in NAVAIRSYSCOM Fixed-Price Incentive Contracts," (Master's Thesis, Naval Postgraduate School, 1973); K. L. Deavers and John J. McCall, Notes on Incentive Contracting (Santa Monica: The Rand Corporation, 1966).

[39] Belden, op. cit., pp. 95-96, 114.

[40] John M. Parker, Jr., "An Examination of Recent Defense Contract Outcomes in the Incentive Environment," (Master's Thesis, Air Force Institute of Technology, 1971).

[41] Ibid, pp. 42-43.

[42] Ibid, pp. 22, 56-59.

[43] John J. McCall, An Analysis of Military Peocurement Policies (Santa Monica: Rand Corporation Memorandum, 1964); J. Ronald Fox, Arming America: How the U. S. Buys Weapons (Boston: Harvard University, 1974).

[44] Hiller and Tollison, op. cit., pp. 239-248.

[45] Ibid, pp. 245-246.

[46] In addition, Parker, op. cit., p. 96, and Belden, op. cit., p. 43, observed a tendency for cost overruns and schedule delays to occur together.

47. Raymond C. Hunt, Janet P. Near and Ira S. Rubin, "Factors that Influence Organizational Performance," Proceedings of the Seventh Annual Acquisition Research Symposium (Hershey, PA: The Federal Acquisition Institute, June, 1978), pp. 270-274.

[48] Raymond G. Hunt and Ira S. Rubin, "Approaches to Managerial Control in Interpenetrating Systems: The Case of Government-Industry Relations," Academy of Management Science, 16 (1973): pp. 296-311. The 19 possible goals of interest were previously identified in: S. Fong and R. G. Hunt, "Incentive Contracting: An Annotated and Classified Modern Bibliography," Technical Report No. 2, NASA Grant NGR 33-015-061 (State University of New York at Buffalo, 1969).

[49] Hunt, Near and Rubin, op. cit.

[50] Raymond G. Hunt, Extra-contractual Influences in Government Contracting, NASA Grant NGR 33-015-061 (State University of New York at Buffalo, 1971).

[51] Scherer, op. cit.; Williamson, op. cit.; Logistics Management Institute, An Examination of the Foundation of Incentive Contracting, LMI Task 66-7 (Washington, D. C.: Logistics Management Institute, 1968).

[52] Booz, Allen, and Hamilton, Inc., Award-Fee Contracting: Criteria and Evaluation Processes, Report to the National Aeronautics and Space Administration (1967); John M. Cummins, "Cost Overruns in Defense Procurement: A Problem of Entrepreneurial Choice Under Uncertainty," (Ph.D. Dissertation, Northwestern University, 1973); Phillip E. Oppedahl, "Understanding Contractor Motivation and Contract Incentives," Defense Systems Management College Study Project Report (May, 1977).

[53] Fox, op. cit., p. 471.

[54] Logistics Management Institute, op. cit., p. 11.

[55] Patrick J. Lynch and John M. Pace, "An Analytical View of Advance Incentivized Overhead Agreements in the Defense

Industry," (Master's Thesis, Air Force Institute of Technology, September 1977), p. 7; also noted by Scherer, op. cit., p. 240.

[56] Scherer, op. cit., p. 158.

[57] Lynch and Pace, op. cit., pp. 6-7.

[58] Hunt, Near and Rubin, op. cit., p. 272.

[59] Logistics Management Institute, op. cit., p. 11.

[60] William F. Hill and Peter A. Shepard, "Effectiveness of Incentive Contracts as Motivators," (Master's Thesis, Naval Postgraduate School, 1973), p. 41.

[61] Hunt, Near and Rubin, op. cit., p. 274.

[62] Hill and Shepard, op. cit., p. 41.

[63] Raymond T. Hunt, Ira S. Rubin, and Franklin A. Perry, Jr., "Federal Procurement: A Study of Some Pertinent Properties, Policies and Practices of a Group of Business Organizations," National Contract Management Journal, Vol. 4, No. 2 (Fall, 1970).

[64] Cummins, op. cit.; also J. M. Cummins, "Incentive Contracts for National Defense: A Problem of Optimal Risk Sharing," The Bell Journal of Economics, Vol. 8, No. 1 (Spring, 1977): 168-185.

[65] Using cost overruns as the dependent variable, one formulation resulted in an adjusted $\bar{R}^2 = .46$ for FPI contracts and $\bar{R}^2 = .73$ for CPIF contracts. Cummins (1973), op. cit., p. 126 and 163, respectively.

[66] Cummins (1973), op. cit., p. 178.

[67] Hunt, Near and Rubin, op. cit., p. 274.

[68] Hunt, op. cit., p. 274.

[69] Jack R. Runkle and Gerald D. Schmidt, "An Analysis of Government/Contractor Interaction as a Motivator of Contractor Performance," (Master's Thesis, Air Force Institute of Technology, 1975).

CHAPTER 3: THE THEORETICAL MODEL

3.1 Introduction

The previous two chapters have provided the necessary justification for replacing the standard 'black box' model of the firm with a structure more representative of actual defense contracting organizations. Due to many market failures discussed in Chapter 1 and the importance of extra-contractual influences identified in Chapter 2, it is argued that selected organizational complexities need to be recognized and incorporated into the basic analysis before the apparent ineffectiveness of contractual incentives will be understood. The normative theoretical models of incentive contracting discussed in the previous chapter have implicitly taken a classical perspective of the firm. The objective of this chapter is to describe a positive model of defense contractor behavior which explains the economic performance of the firm by focusing on the resource allocation decision process of its organizational units.

The traditional theory of the firm, in many respects, may be thought of as an adjunct to a more comprehensive theory of general economic phenomena. As such, it is primarily concerned with the microassumptions necessary for aggregation rather than the microbehavior of the individual firm. The classical assumptions of atomistic competition, homogeneous products, perfect knowledge and the profit maximizing motive of autonomous business firms is consistent with the objective of aggregate

macro-analysis. The theory of the firm in this context is a theory of resource allocation among competitive markets via the pricing mechanism. The economic behavior of the classical business firm is completely determined by and necessarily consistent with its external macroeconomic environment.

However, as the classical assumptions of perfect competition break down, the need to examine the internal operation of the firm as it affects economic performance becomes more pronounced. If the assumptions are clearly violated, the behavior of the firm (or industry) may not be accurately characterized as passive and completely predetermined by exogenous factors. As noted by Williamson:[1]

> "When the conditions of competition are relaxed . . . the opportunity set of the firm is expanded. In this case the behavior of the firm as a distinct operating unit is of separate interest. Both for purposes of interpreting particular behavior within the firm as well as for predicting responses of the industry aggregate, it may be necessary to identify the factors that influence the firm's choices within this expanded opportunity set and imbed these in a formal model."

The following section will provide an overview of the formal model as developed by Cyert and March in A Behavioral Theory of the Firm.[2] The next section will present the model as formulated for our particular purposes.

3.2 The Behavioral Theory of the Firm: An Overview

The behavioral theory of the firm as developed by Cyert and March is a synthesis of the economists classical theory of the firm with theories of administrative organization and cognitive processes.[3] The basic difference between the classical and behavioral theories is that the latter has as its primary unit of analysis decision making units within the organization rather than the organization as a whole. The classical firm solely controlled by the owner/entrepreneur is replaced with a coalition of individuals or sub-coalitions which collectively define the organization and its boundaries. Decision responsibility is recognized to exist among various organizational units (individuals and/or sub-coalitions) rather than being centralized in a single decision maker. Furthermore, while multiple decision makers operate within the confines of an organizational structure, they are assumed to behave in an autonomous fashion except in periods of organizational conflict. Thus, the behavioral firm is viewed as a loosely coupled system of quasi-independent decision making units--not an autonomous organization dominated by a singular decision maker.[4]

While both theories view the firm as teleological, the nature of the assumed organisational goals further distinguishes the classical and behavioral theories of the firm.[5] The behavioral theory recognizes that organizational goals other than profit may be of concern to the decision making units and have a direct influence on resource allocation decisions--and ultimately, the

firm's economic performance.[6] Furthermore, the goals of the various decision making units are not necessarily consistent, nor is an organizational joint preference ordering required--i.e., conflict among decision makers and required tradeoffs among various organizational goals are explicitly considered.[7] The goals of the decision making units may be pecuniary or non-pecuniary and are not required to be invariant. Finally, all organizational goals need not be recognized and attended to each decision period as lower ranking concerns may be in conflict with higher priority (and temporarily dominating) concerns.

An important difference between the classical and behavioral theories of the firm concerns the assumed cognitive abilities of the relevant decision makers.[8] The classical theory assumes the owner/entrepreneur capable of optimally converting a finite number of factor inputs into outputs by the instantaneous analysis of all feasible alternatives at the margin. This requires, among other things, full and complete information (or relevant probability distributions) concerning all feasible production technologies, factor input supply functions and output demand functions. Decision makers in the behavioral theory, on the other hand, possess bounded (rather than omniscient) rationality and information concerning decision alternatives is neither complete or fully comprehended. This suggests that operational goals are specified as finite aspiration-levels rather than directives to maximize.[9] An additional side-effect of recognized limits on information and rationality within the behavioral

model concerns the existence of organizational slack--payments to factor inputs (e.g., employees) in excess of that required to sustain the organization--whereas in the classical firm all profits accrue solely to the owner/entrepreneur. Finally when additional information is desired by decision making units in the behavioral theory, it is not automatically available but must be searched for.[10] Therefore, instead of basing decisions on perfect information or knowledgeable estimates of the operating environment, the decision maker of the behavioral model is reliant on feedback data and traditional decision rules in contrast to uniquely formulated decision alternatives.

The organizational, motivational, and cognitive assumptions which distinguish the behavioral and classical theories of the firm result in conceptually distinct operational behavior from their respective decision making units. The implied decision process of the classical firm suggests an all-encompassing profit maximizing set of decisions instantaneously made by the owner/entrepreneur. The behavioral firm describes the organizational decision process in terms of multiple decision makers pursuing multiple (and potentially inconsistent) goals within an operational environment characterized by dynamic aspiration-levels, limited information availability, and organizational conflict. Constrained by bounded rationality, decision makers in the behavioral model avoid uncertainty by buffering their respective goals from external shocks. This involves decision makers attempting to influence the environment through negotiation or pressure (as opposed to passive

acceptance) and promoting (ratner tnan minimizing) organizational slack. Furthermore, the organizational decision process of the behavioral firm is reliant on standard operating procedures which determine the relative importance of the multiple goals, the decision choices utilized to achieve the goals, and the search procedures utilized to identify (only when necessary) additional decision alternatives.

In conclusion, rather than assuming instantaneous static equilibrium adjustments exclusively determined by exogenous factors, the behavioral theory of the firm considers a dynamic organizational decision process influenced by the structure of decision responsibility among multiple organizational units as well as the motivational concerns and cognitive abilities of the relevant decision makers. The following section will apply these basic concepts in specifying a behavioral model of the firm applicable to defense contracting organizations.

3.3 Model Description

We view the large business firm as a goal directed decision making system or coalition representing a number of diverse constituencies (e.g., owners, employees, consumers, etc.). The types of constituencies under consideration are dependent on the imposed system boundaries and the decision making unit of analysis. These and other system attributes are necessarily determined by the nature of the problem being addressed. Our objective here is to develop a positive model of firm behavior based on an analysis of the decision making process of its organizational units with respect to internal resource allocation.

3.3.1 The Firm's Goals

Two types of goals are considered--superordinate goals and operational goals.[11] Superordinate goals are devoid of any specific measure and are generally agreed upon by all system participants. Superordinate goals are relevant to our analysis only to the extent which they explain the formation and continued existence of a coalition of diverse participants. They are purposely ill-defined and may be viewed as policy statement inducements to potential and actual coalition members rather than having a direct influence on the resource allocation decision making process.

Operational goals, on the other hand, are specific, measurable aspiration-level objectives of the various coalition members and are central to the decision making process.[12] They may alternatively be viewed as side payments demanded by the various system participants which must be satisfied in order to make the coalition viable. The source of such demands may be the subjective translation of the agreed upon superordinate goals or the operational expression of personal aspirations by the constituency groups or individuals comprising the system. In any case, they are operational and form the nucleus of the decision making process. The system is explicitly directed towards the satisfaction of the constituency/individual goals/ demands made by coalition participants. Whether the form of payment is pecuniary or non-pecuniary, all demands are assumed to exist in a measurable form in the firm's operational goal vector if they influence internal resource allocation.

Because of the diverse needs and objectives of the various coalition participants, operational goals of the system may be inconsistent and in conflict with one another--i.e., a joint preference ordering may be undefined. The relative influence of the various operational goals on system behavior will be determined by the bargaining power of the source of the demand and the perspective of individual decision makers in the organizational structure.

3.3.2 Organizational Structure

Coalition members are motivated to create an organizational structure of control which will enforce and monitor the side payments (or operational goals) representing demands of the participants. This involves the internal allocation of functions and responsibility to specific sets of individuals within the system. The process of developing such an organizational structure may be viewed as sub-coalition formation. Each sub-coalition is primarily responsible for satisfying a sub-set of the operational objectives and is assumed to control decision variables linked to resource allocation which facilitate goal achievement. The composition of the operational goals and decision variables assigned to a particular sub-coalition are determined by the bargaining power of the coalition participants and are assumed to be relatively stable.

We are now in a position to define the formal boundaries of the system. If a constituency has objectives represented in the operational goal vector that are enforced by a sub-coalition having influence on internal resource allocation, we will consider the constituency internal to the system. Note that the sub-coalition need not be within the traditional organization structure of the firm (e.g., DOD, Unions, EPA).

While a particular sub-coalition may be responsible for a specific set of operational objectives, this is not meant to imply that the achievement of a particular goal is solely

determined by the actions of that sub-coalition. The collective behavior of many sub-coalitions (and other exogenous factors) will determine the success of achieving a particular goal. In addition, the nature of the operational goal vector may very well result in sub-coalitions, or even a single sub-coalition, striving to achieve objectives that are in conflict. This suggests the need for two mechanisms: 1) a pressure mechanism representing attempts of sub-coalitions to influence one-another in order to achieve their particular operational goals, and 2) a mechanism which resolves individual sub-coalition conflict when attempting to simultaneously satisfy inconsistent goals.

The present model will focus on the interaction of the decomposed system's sub-coalitions and their decision making process with respect to resource allocation. Before describing this process, we must first introduce our decision making unit of analysis.

3.3.3 Unit of Analysis

Individual managers responsible for specific sub-coalition goal achievement will be our decision making units of analysis. In addition to achieving specific operational goals assigned to a sub-coalition, the sub-coalition manager is assumed to strive for personal goal achievement. Again, we will restrict consideration of personal objectives to measurable aspiration-level operational goals. On-going organizations are assumed

to be relatively stable with respect to the importance sub-coalition managers place on assigned operational goals and their own personal goals. The aspiration-levels of all operational goals, including personal goals, are assumed to change over time as a result of (among other things) continued achievement or failure.

Several assumptions concerning the behavioral attributes of our coalition participants have already been implicitly made and are primarily a result of recognized limits on the rationality of the system's decision makers. Sub-coalition managers have bounded rationality. They are considered incapable of optimizing a given goal (or utility function) based on a marginal analysis of all possible alternatives and objectives due to the unreasonable demands (in the form of computational and informational assumptions) this behavior makes on the cognizance of the decision maker. Thus, operational goals are given as specific measurable aspiration-levels (rather than directives to maximize) and must be considered sequentially (rather than simultaneously). In addition, responsibilities for system performance have been decoupled and assigned to specific sub-coalitions via the formation of an organizational structure. This similarly recognizes the effective decision capacity of a given individual with respect to resource allocation decisions.

Finally, the computational demands required to effectively deal with uncertainty suggest that decision makers will seek out

non-stochastic decision situations whenever possible. This results in short-term decisions based on standard operational procedures and feedback data rather than long-range planning based on unique problem solving techniques, certainty equivalence estimation or forecasting. When heuristic approaches fail to provide an acceptable solution to the problem (defined as an unsatisfied operational goal), decision makers will reluctantly search for alternatives. Search is not comprehensive, as suggested above or voluntarily offered. It is solely motivated by the recognition of a problem.

3.3.4 Organizational Slack

We have previously described the firm as a system or coalition attempting to satisfy a diverse array of constituency demands via pecuniary and non-pecuniary side payments. If the side payments made to the various coalition members are adequate to keep them in the coalition we consider the coalition viable. Organizational slack is defined as payments to participants in excess of that amount necessary to sustain a viable coalition. There are several reasons why we can no longer assume organizational slack to be zero for all non-owners, as in the classical theory of the firm.

Side payments are made to coalition members in a variety of different forms, including policy or operational goal definition, which makes the minimum factor prices necessary for coalition viability difficult to ascertain. In addition, sub-

coalition managers are motivated to create slack because it may be considered a means to achieving their personal goals and/or avoiding uncertainty. In any case, organizational slack plays an important role in explaining the firm's response to changes in its external environment.[13] Aspiration-levels representing the demands of the various coalition members, while not considered fixed, adapt slowly relative to changes in the firm's operating environment. If organization slack were zero, we would expect a great deal of organization instability in economic downturns--i.e., the firm would dissolve due to insufficient side-payments. Thus, organizational slack absorbs a great deal of the environmental variability and explains the continued existence and stability of the firm.

3.4 The Decision Making Process

In order to analyze the decision making process of sub-coalition managers with respect to internal resource allocation, it will be necessary to specify the concepts, mechanisms and decision variables alluded to above. However, a brief summary of the decision environment at this point may help to identify the salient aspects of our behavioral perspective of the firm.

We have based our analysis on the assumption that the aspiration-level operational goals of the firm are the focal point of internal resource allocation decisions. Furthermore, responsibility for attainment of these possibly conflicting goal/demands is partitioned among specific sub-coalitions--even though the collective actions of many sub-coalitions may determine the success of achieving a particular goal. Sub-coalitions are considered internal to the firm if they are responsible for a sub-set of the operational goals and have an influence on internal resource allocation.

Our unit of analysis is the manager in charge of a specific sub-coalition. In making resource allocation decisions, he faces an assortment of operational goals; some of which he views as his functional responsibility, some represent his personal goals, and some are considered operational constraints--the violation of which will result in pressure being applied by the sub-coalition manager or organizational unit primarily responsible

for its attainment. A premier objective of the behavioral model is to reduce the magnitude of the demands implicitly made by the classical theory on the rationality of the decision maker to more reasonable proportions. This requires constraining the number of goals that are of immediate operational concern to the project manager in a given decision period; determining the relative priorities of each concern and the order of sequential attendance; limiting the set of possible decision alternatives considered; and finally, adjusting the desired aspiration-levels of each (active) operational goal.

3.4.1 Elements of the Decision Environment

We are now in a position to define the following:

$S \equiv$ a vector of operational variables, x_n, which collectively define the state of the system from the perspective of a given decision maker.

$X \equiv$ a vector of operational variables, x_i, which are of immediate concern to the decision maker where $x_i \varepsilon x_n$.

$G \equiv$ a vector of operational goals which specify the desired aspiration levels, g_i, of each x_i in X.

$V \equiv$ a two-valued (0,1) operational objective function that determines which x_i's in x_n are of concern to the decision maker.

$\bar{X}$ ≡ a rank ordering of the x_i's in X in terms of priority attendance.

Π ≡ attention rules which define $\bar{X}$.

A ≡ the set of possible resource allocation decision alternatives.

Σ ≡ search rules that determine which alternatives are actually considered $\mathring{A}$ where $\mathring{A} \epsilon A$.

Δ ≡ decision rules that determine which alternative will be chosen, a, from the set of considered alternatives, $a \epsilon \mathring{A}$.

Φ ≡ external factors that affect S but are beyond the direct control of the decision maker.

θ ≡ a random state-of-nature.

Ω ≡ an outcome function which determines S.

Ψ ≡ a pressure mechanism representing either attempts of the decision maker to influence Φ ($\dot{\Psi}$) or attempts of the j^{th} organizational unit to influence X (${}_j\bar{\Psi}$).

Υ ≡ a goal adjustment mechanism.

3.4.2 The Decision Process

The following is a general description of the process by which a sub-coalition manager may be thought to reach decisions with respect to resource allocation and pressure application in a given decision period:

I. Observe Feedback

$$S_t = \Omega(a_{t-1}, \Phi_{t-1})$$

$$\Phi_{t-1} = \phi(\dot{\Psi}_{t-1}, \theta)$$

II. Identify Problems

$$X_t = V(S_t, G_t, \dot{\Psi}_t) \cdot S_t$$

III. Set Priorities

$$\overline{X}_t = \Pi(X_t, {}_j\overline{\Psi}_{t-n})$$

IV. Consider Alternatives

$$\overset{\circ}{A}_t = \Sigma(\overset{\circ}{A}_{t-1}, X_{t-1}, A)$$

V. Choose Alternative

$$a_t = \Delta(\overset{\circ}{A}_t, X_{t-n}, \overline{X}_t)$$

VI. Apply Pressure

$$\dot{\Psi}_t = \Psi(\Phi_{t-1}, X_t)$$

VII. Adjust Goals

$$G_{t+1} = \Upsilon(G_{t-n}, X_{t-n})$$

The project manager's decision process is initialized by the observance of feedback information concerning the effect of past decisions a_{t-1} and external factors Φ_{t-1}, on the current state of the system S_t. Although attempts may be made to influence Φ_{t-1} through ϕ by the application of pressure $\dot{\Psi}_{t-1}$, the uncontrollable state of nature θ results in the project manager having less than perfect knowledge concerning the affect of a_{t-1} on S_t via the outcome function Ω. The operational objective function V, which determines which elements

X_n of S_t are of concern (e.g., problems) to the project manager X, is a function of the pressure received from other organizational units $\overline{\Psi}_t$, previously defined operational goals G_t and S_t. The relative importance of the various elements X_i in $\overline{X}_t$ is determined by standard attention rules. Attention rules Π are influenced by the source and severity of received pressure ${}_j\Psi_{t-n}$ and, of course, X_t.

Only a subset of all possible alternatives A are considered by the project manager in a given decision period. The subset of considered alternatives $\overset{o}{A}_t$ is modified by a search function Σ only when previous concerns X_{t-1} have not been satisfactorily attended to by the standard set of decision alternatives $\overset{o}{A}_{t-1}$. The choice of a particular alternative a_t in $\overset{o}{A}_t$ is determined by routine decision rules Δ based on past experience X_{t-n} and current priorities $\overline{X}_t$. The project manager will apply pressure $\dot{\Psi}_t$ dependent on current concerns X_t, the influence of external factors Φ_{t-1} on S_t, and the perceived effectiveness of $\dot{\Psi}_t$ in influencing the actions of other organizational units through Ψ. Finally, the aspiration-level goals G_{t+1} are modified via the goal adjustment mechanism γ based on previous goals G_{t-n} and problems X_{t-n}.

3.5 Conclusion

This chapter has described a positive model of firm behavior based on the operational environment, interaction, motives and limited cognizance of multiple decision making units within the organization. Eight difference equations in the previous section provide an abstract characterization of a single sub-coalition manager's decision process. However, in order to investigate the economic performance of the firm as determined by the dynamic interaction of multiple organizational decision makers, a more comprehensive (but at the same time detailed) methodological approach will be necessary. Such a methodology, computerized decision process simulation modeling, is discussed in the following chapter.

Footnotes - Chapter 3

[1] Oliver E. Williamson, The Economics of Discretionary Behavior: Managerial Objectives in a Theory of the Firm (Englewood Cliffs, N. J.: Prentice-Hall, 1964), pp. 2-3.

[2] Richard M. Cyert and James G. March, The Behavioral Theory of the Firm (Englewood Cliffs, N. J.: Prentice-Hall, 1963).

[3] Cyert and March, op. cit., see also, for e.g.,; H. A. Simon, Administrative Behavior, 3rd edition (New York: MacMillan, 1976); J. G. March and H. A. Simon, Organizations (New York: Harper and Row, 1954).

[4] March and Simon, op. cit., p. 159.

[5] However, not all behavioral models are necessarily teleological. See M. D. Cohen, J. G. March, and J. P. Olsen, "A Garbage Can Model of Organizational Choice," Administrative Science Quarterly, 1972, 17, pp. 1-25.

[6] See Oliver E. Williamson, "A Model of Rational Managerial Behavior," Chapter 9 in Cyert and March, op. cit., for an example of a general preference function (as opposed to profit) maximizing model of the firm.

[7] March and Simon, op. cit., Chapter 5.

[8] The initial formal treatment of bounded rationality is Herbert A. Simon, "A Behavioral Model of Rational Choice," Quarterly Journal of Economics, February 1955, 69, pp. 99-118.

[9] See March and Simon, op. cit., pp. 140-141.

[10] For an early treatment of search behavior see Herbert A. Simon, "A Formal Theory of the Employment Relation," Econometrica, July, 1952, 20, pp. 40-48; also, for discussion March and Simon, op. cit., p. 49.

[11] Arie Y. Lewin and Michael Schiff, Behavioral Aspects of Accounting (Englewood Cliffs, N. J.: Prentice-Hall, 1974), pp. 5-7.

[12] See March and Simon, op. cit., p. 155 for a discussion of operational and non-operational criteria.

[13] The role of slack as an organizational stabilizer in imperfect market conditions is found in R. M. Cyert and J. G. March, "Organizational Factors in the Theory of Oligopoly," Quarterly Journal of Economics, 1956, 70, pp. 44-64.

CHAPTER 4: MODEL STRUCTURE

4.1 Introduction

As demonstrated in Chapter 2, in order to better understand the apparent failure of incentives to influence contractor behavior, it is necessary to develop insights into the organizational, environmental, and motivational structure of resource allocation decision making within the firm. The purpose of this chapter is to provide a general description of a decision process simulation model of defense contractor behavior and performance based on the theoretical and empirical findings of earlier chapters.

The decision process model (DPM) is designed to simulate the actions and operating environment of a project manager within a defense contracting organization and the interdependent actions of corporate-level and DOD management personnel. Due to the complexities involved with the development and verification of a dynamic simulation model which realistically considers the major contractual and extra-contractual determinants of contractor behavior, it is necessary to decompose the DPM into discrete components (sub-models). The next chapter discusses the detailed specification of the various sub-models followed by a description of the simulation results.

4.1.1 Background

Findings of existing research, as previously discussed, suggest that the goal structure of contractors consists of survival, growth, market share and prestige as well as profit.[1] The relative operational importance of these goals is influenced by the positions and responsibilities of the relevant decision makers within the organization. The structure of contractor organizational decision making is (by necessity) decentralized, and multiple decision makers are fairly autonomous in pursuit of their respective operational goals. In any case, survival is perceived to depend on attaining the project performance objectives which affect future company image and the ability to obtain future business. Maintaining quality technical and administrative personnel, even in the face of declining business activity, is perceived to be critical to maintaining competitive positions. Likewise, growth in market share is pursued as a means to improve internal capabilities and as a means to spread fixed costs over a larger base. In short, contractor management (at various levels) sacrifices short run profits on specific contracts in favor of securing new business, promoting technology spinoffs to commercial businesses, improving opportunities for follow-on projects, acquiring or maintaining quality personnel in scarce disciplines, and/or gaining competitive advantage by engaging in developmental research instrumental to future products.

The ability of a contractor to continuously behave as if short run profits do not matter depends on satisfying or exceeding a minimum required level of cash flow in each period. In other words, from period to period a contractor concentrates on achieving survival, growth and prestige goals subject to not violating cash flow constraints--i.e., cost recoveries over all projects in a given period equal to or exceeding actual costs. While a firm in the market environment affects revenues by the control of such variables as price, product attributes, production levels, inventory, etc., the defense contractor has little operational control over standard economic decision variables as they are determined ex ante by negotiation. Revenue is based on cost recovery type contracts (regardless of incentive structure); specifically on the recovery of direct and indirect costs. A fundamental failure of past research has been the lack of a clear cut understanding of the differences between doing business in the traditional market environment and the defense contracting environment described above.

4.1.2 Research Considerations

The research approach utilized involves the development of a computer simulation model which describes the internal decision making process of defense contractors at the project and corporate levels. An objective of this research effort is to develop a capability to model the potential impact of various incentive schemes on the performance of DOD contractors. It

is therefore necessary to incorporate in the simulation model such basic elements as: DOD project goals, DOD incentive mechanisms, contractor goals, and contractor organizational response mechanisms.

The key goals of the contractor as mentioned above include survival, profit, growth, market share, and prestige. The contractor organizational response mechanisms utilized in their attempt to achieve their own goals (subject to DOD pressure and project constraints) comprise an important segment of the modeling approach. For example, the use of the IR&D account when the backlog is thin can help smooth out the workload and improve cash flow; but this action may also impact the contractor's total costs and ultimate project performance. Similarly, DOD project goals may be affected by contractor attempts to: reduce profit margins and/or increase cost sharing on new proposals when the backlog of contracted work is low; renegotiate overhead agreements when cash flow is inadequate; increase subcontracting when backlog is excessive; transfer quality individuals off project work to help develop new proposals; assign extraneous (non-direct) personnel to a project budget to improve cash flow and reduce overhead; and, finally, renegotiate project performance, attribute, schedule, and/or cost agreements when serious problems are identified. Thus, it is clear that in general the DOD project goals and the control goals are not congruent, and that the ability of the DOD to accomplish improvements in project goals depends

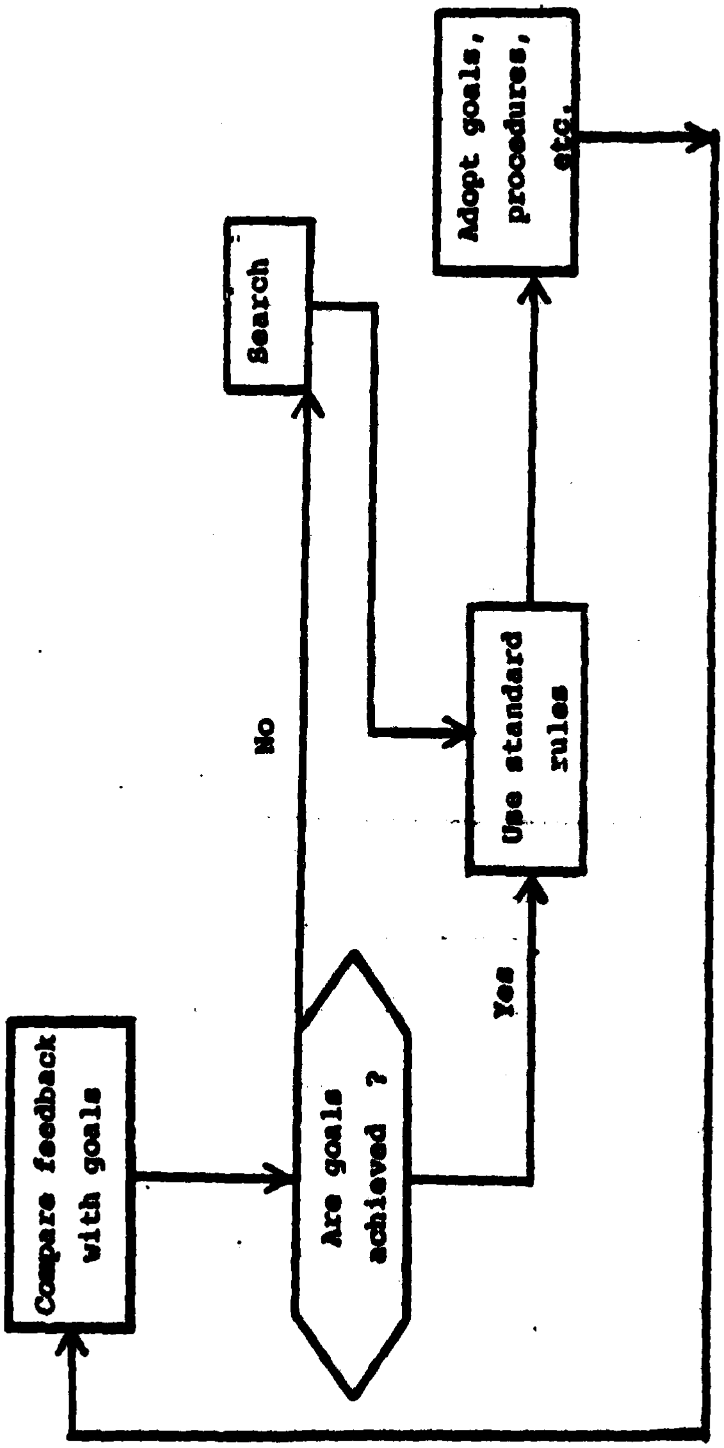
on modifying the contractor's behavior in pursuit of their own goals.

The general modeling framework assumes that there are several goals that the firm is seeking to satisfy and whenever it appears through feedback data that these goals cannot be achieved (that is when performance has or is expected to fall short of goals), search activity is triggered. This causes the firm's decision makers to search for new ways of behaving and may also lead to a downward revision of goals. On the other hand, when it appears that goals are being achieved, standard operating procedures are evoked without any search activity. In summary, the total process governing contractor actions consists of a system of feedback, adaptation, and search efforts with the contractor's goals as a starting point and with performance results indicative of the degree to which both project and corporate level goals are met. This feedback, adaptation and search process is illustrated in Exhibit 4.1.

It is important to note that the various elements of this process which collectively define the behavioral pattern of the DPM have been segregated and parameterized. This allows the DPM to be modified as necessary to analyze different initial conditions, behavioral assumptions, organizational structures, response mechanisms, incentive schemes, etc. The application of this important design consideration is demonstrated in Chapter 6

Exhibit 4.1

Feedback, Adaptation and Search[2]



4.2 Model Hierarchy

The DPM operates on three hierarchical levels; the project manager level, the corporate level, and the DOD level. Each level contains a separate set of goals and expectations. The synthesis of these goals into an operational plan by the project manager is the foundation of the DPM. This section discusses how the various levels interact with one another followed by placement of the operational goals into the project manager's attention hierarchy. The following chapter provides a more detailed description of the various goals and organizational response mechanisms.

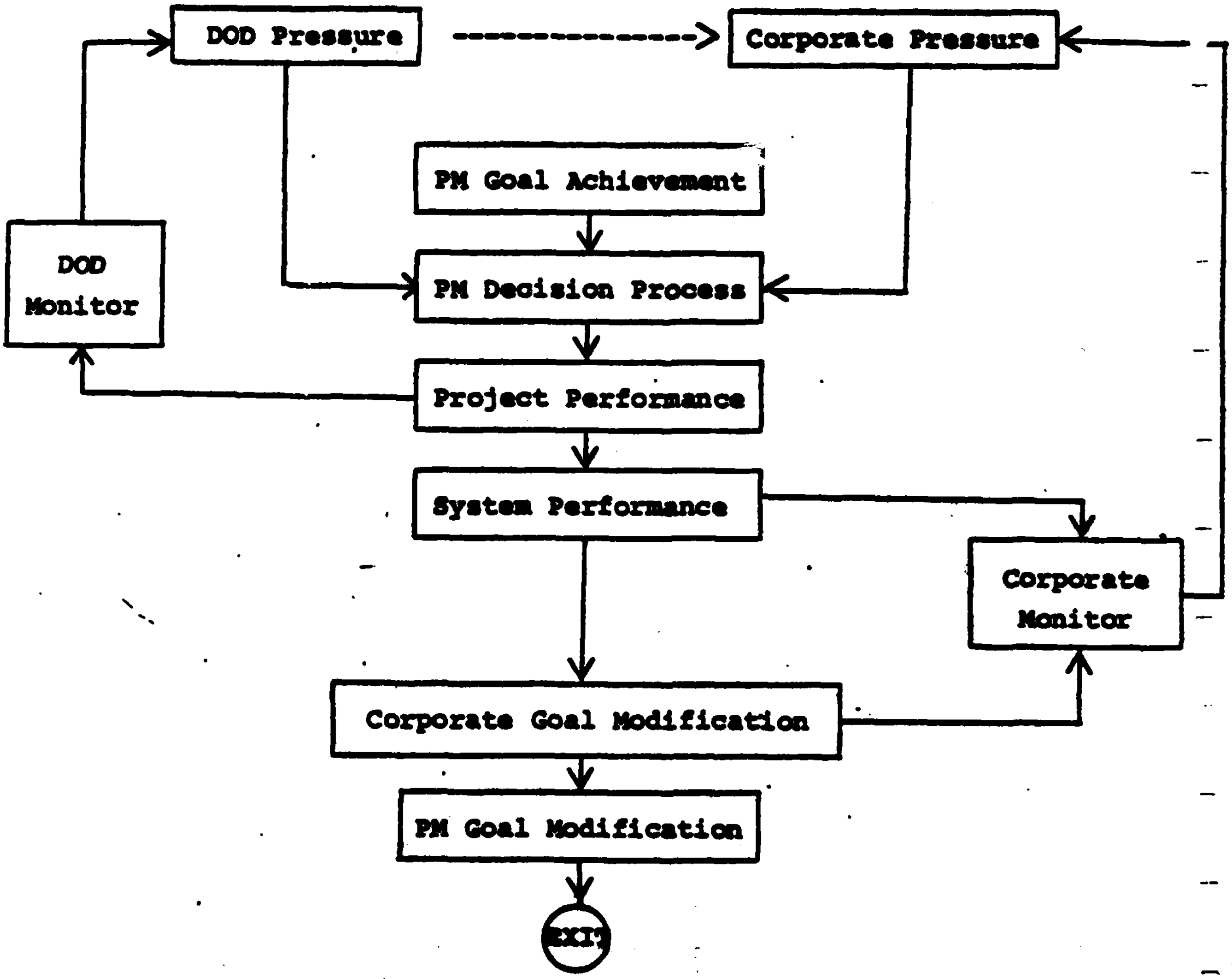
4.2.1 Organizational Structure and Interaction

Exhibit 4.2 shows how the project manager, corporate and DOD organizational levels interact with one another during the course of a simulation. The personal goals of the project manager are centered around the maintenance of a level of backlog within specified boundaries. If the Backlog Goal is satisfied, consideration is given by the project manager to his staff or Volume Goal. Obviously, the two goals are related--as the size of the project manager's staff increases the number of months of backlog decreases, ceteris paribus. The project manager strives to satisfy these dynamic aspiration-level goals in the absence of pressure from the corporate or DOD level.

The DOD is assumed to be primarily concerned with the quality and scheduling of work performed on specific contracted

Exhibit 4.2

DOD/Corporate/PM* Interaction



* Project Manager

projects. DOD project goals are assumed static and defined with the initial awarding of a contract. The DOD is able to monitor the project manager's monthly (but lagged) performance and discern when the quality of specific projects is unsatisfactory. When this is the case, the DOD applies pressure directly on the project manager to improve performance. If this strategy is ineffective, the DOD may apply pressure at the corporate level, presumably to be relayed to the project manager. An otherwise complete project is not accepted by the DOD until the minimum quality standard has been achieved. The DOD is assumed incapable of determining if a project is behind schedule until it is discovered the project is not completed on the prearranged delivery date. When this is the case, Schedule Pressure is applied to the project manager by the DOD. Finally, the project manager is unable to over-bill a given contract and must absorb any excess costs incurred.

In contrast to the DOD, the corporate level is not directly concerned with individual project performance (unless pressured by the DOD as mentioned above) but instead focuses on overall system performance. Specifically, the corporate level concerns itself with the cumulative cash flow performance of the project manager's organization. When this falls below prespecified levels, Corporate Pressure is applied on the project manager to increase DOD billings and/or decrease expenses. The corporate level goals, as well as the project manager's are dynamic and modified throughout the course of a simulation.

In summary, the interaction of the organizational levels and their associated goals and expectations combined with the many operational factors and constraints faced by the project manager provides a realistic setting for the project manager's decision process. The following section describes standard attention rules which enable the project manager to formulate operational plans in this complex decision environment.

4.2.2 Multiple Goals and Pressures

Exhibit 4.3 provides a listing and ranking of the pressures and goals facing the project as they are incorporated into the DPM logic flow. The actual behavior instigated by these behavioral determinants are considered in the following chapter. At this point consideration is given to the project manager's priority ranking only. Subsequent sections discuss the DOD and corporate-level hierarchy of concerns.

The paramount concerns of the project manager are Corporate Cash Flow Pressure and DOD pressures related to overdue or incomplete projects--i.e., DOD Schedule Pressure and/or Deficient Quality Performance on an otherwise completed project. The project manager is assumed to address these occurrences before considering remaining problems. Other pressures and unsatisfied goals are not ignored but are given secondary consideration if they are in conflict with higher ranking priorities.

The next level of influence on project manager behavior concerns DOD quality pressure relayed from the corporate level,

Corporate Quality Pressure. As mentioned above, the DOD only approaches the corporate level with quality concerns if previous Project Manager-level Quality Pressure has been ineffective. As noted in Exhibit 4.3, this may often be the case as the Backlog Goal of the project manager takes precedence over Project Manager Quality Pressure. Finally, the Volume Goal of the project manager is the lowest ranking consideration in the attention hierarchy.

Exhibit 4.3

Hierarchy of Determinants of PM Behavior

Level 1: Corporate Cash Flow Pressure
DOD Schedule Pressure
Deficient Quality Performance on Completed Project

Level 2: Corporate-Level DOD Quality Pressure Relayed to PM

Level 3: Deficient Backlog Relative to PM Goal

Level 4: PM - Level DOD Quality Pressure

Level 5: Deficient Volume Relative to PM Goal

4.3 Project Differentiation

4.3.1 Major Projects and Spinoff Projects

The project manager's backlog is assumed to consist of two types of projects: Major Projects and Spinoff Projects.[4] This section of the report discusses several important differences which distinguish Major from Spinoff projects. The following section discusses the specific attributes of individual contracts.

The most obvious difference between Major and Spinoff projects concerns the magnitude of the project size. Major Projects are typically 10 to 20 times larger than Spinoff Projects--both in dollars budgeted and required man-months of work. In addition, the duration of a Major Project is assumed to be 42 months while Spinoff Projects range from three to 18 months.

The project manager is able to influence the awarding of Spinoff projects through proposal writing efforts while decisions to instigate a Major Project proposal are made and financed at the corporate level. Allocations levied on the project manager's operation finance corporate level IR&D which in turn supports the solicitation of new Major Projects from the DOD. Once the contract is awarded, it is assigned by corporate to a project manager.

The DOD monitors the quality of work performed on the Major Project while Spinoff Projects are awarded on a best-

effort basis only. Finally, the Major Project is not considered complete by the DOD until the minimum quality standard is achieved. A Spinoff Project, on the other hand, is considered complete once the required man-months of work has been performed.

4.3.2 Project Attributes

All contracts of awarded projects specify a standard quality of man-months (SQMM's) of work to be performed, a dollar budget, and a delivery date. In addition, Major Projects contain a quality goal which is monitored and strictly enforced by the DOD. Note that low quality personnel, if used exclusively on a particular project, would eventually complete the SQMM requirement. However, consideration of the project's other attributes by the project manager--specifically budget and quality attributes--limits this type of behavior.

The relationship of the dollar size of a contract to the SQMM balance is a function of the existing quality composition of the workforce and the salary rates of high and low quality personnel. (Negotiated overhead rates and fees are also included.) The salary differential between high and low quality workers is not justified by their marginal products--i.e., the difference in productivity between high and low quality personnel is larger than their difference in salary. This suggests that if low quality workers were used exclusively on a given contract, the dollar

budget would be exhausted sooner than the SQMM balance. The cost overrun which results from this type of behavior prevents the project manager from using only low quality workers on a particular project.

In addition, Major Projects contain a cumulative quality index which measures the quality of work performed. If the quality measure falls below the negotiated minimum standard--which happens eventually if only low quality workers are used--DOD Quality Pressure is applied at the project manager and/or corporate levels. This occurrence, as mentioned earlier, instigates the use of high quality personnel on the Major Project. Finally, each Spinoff Project is assigned a delivery date when the project is initially awarded with the duration of a project related to the size of the newly-awarded contract.

4.4 Labor Force Dynamics

4.4.1 Project Manager Control

It is assumed in the DPM that there is a greater availability of low quality workers than high quality workers in the labor pool from which the project manager must choose new employees. Consequently, a limit exists on the number of high quality workers which may be hired in a given period. It is assumed the project manager is always able to fill out labor requirements with low quality personnel.

Because of the relative scarcity of high quality workers, oftentimes the project manager may hire high quality workers even though a general hiring decision has not been made. It is assumed the project manager always chooses to hire the high quality workers that become available unless firing is currently taking place. Of course, only low quality personnel are fired by the project manager.

4.4.2 Labor Force Attrition and Quality Composition

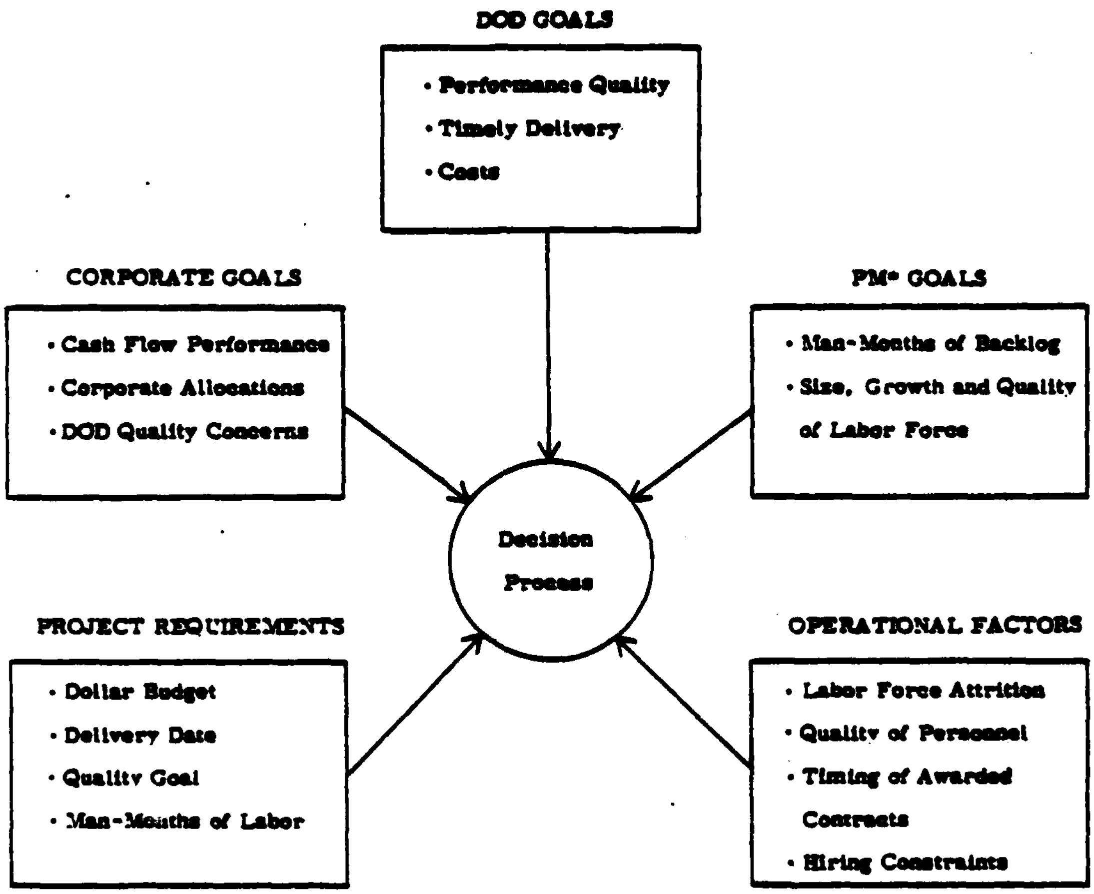
The DPM assumes differences exist between the rates of attrition of high and low quality workers, and that they are non-constant. Attrition rates vary depending on employee perception of the current health of the project manager's organization.

High quality personnel are assumed to have higher attrition rates than their lower quality counterparts. Furthermore, in periods of prolonged labor force contraction, the attrition rate of high quality workers increases. Labor force attrition is clearly beyond the direct control of the project manager but has important dynamic effects on the overall quality composition of his workforce. The overall quality of the labor force is a function of the proportion of the workforce considered high and low quality. It is obvious that given the previously mentioned hiring/firing constraints and the fluctuating rates of attrition, the quality composition of the labor force behaves in a very dynamic fashion.

4.5 Decision Environment

It is now possible to generally describe the decision environment of the project manager. The DPM consists of eight loosely coupled sub-models (introduced in the next section) which operate on three organizational levels: the project manager level, the corporate level, and the DOD level. Each organizational level contains a separate set of goals, response mechanisms, and decision processes which are simulated by the appropriate sub-models. Likewise, the various operational constraints mentioned above are simulated by appropriate sub-models. Thus, the project manager's actions are influenced simultaneously by his personal goals, the size and profitability of existing contracts, the availability and quality of labor, the capture rate and attributes of new contracts awarded by the DOD and, finally, the goals and pressures of corporate level and DOD management. The synthesis of these various goals and constraints into an operational plan by the project manager, as illustrated in Exhibit 5.4, is the foundation of the DPM.

Exhibit 4.4



*Project Manager

4.6 Sub-Model Introduction

4.6.1 General Description

This sub-section briefly describes each sub-model of the DPM. Chapter 5 describes the mechanics of each sub-model in greater detail. The objective here is to focus on how the multi-level operating environment and decision process of the simulation model has been decomposed into discrete components. The following sub-section discusses the sub-model solution sequence and work flow.

PM Manpower Assignment Sub-Model

The objective of the PM Manpower Assignment Sub-Model is to assign each high and low quality worker to indirect proposal writing activities or to a specific project. As discussed above, the project manager (PM) is assumed to make allocation decisions based on the existence of various DOD and corporate pressures, the achievement of personal goals, and the individual constraints posed by the inventory of incomplete projects.

Project Update Sub-Model

Based on the allocation decisions made by the project manager with respect to the quantity and quality of work performed on each project, several running measures must be updated for each project worked on. Specifically, the remaining dollars in the budget and the required SQMM balance must be decreased

and the quality index of work performed adjusted accordingly. Finally, the time remaining before each project is due is calculated.

Personnel Sub-Model

The objective of the Personnel Sub-Model is to implement the decisions made by the project manager with respect to alterations in the size of the workforce subject to the constraints mentioned earlier in this chapter. Labor force attrition is also reckoned with in this sub-model and is assumed to occur simultaneously with the project manager's hiring/firing decision--i.e., the project manager is unable to compensate for attrition in the current period. The output of the Personnel Sub-Model is a description of the end-of-the-period labor force in terms of size and quality composition.

Backlog Determination Sub-Model

Based on the output of the previous sub-models, the Backlog Determination Sub-Model calculates the number of months of backlog the project manager has in the incomplete project inventory at the end of the period. This involves determining whether a project has been awarded and, if so, the dollar and SQMM size of the new project.

Cash Flow Determination Sub-Model

The Cash Flow Determination Sub-Model calculates the direct

and indirect costs associated with the project manager's operation and the cumulative billings to the DOD allowed by the direct work force associated with individual projects. Of course, billings against a particular contract are allowed only if the project budget has not been depleted.

Corporate Goal Adjustment Sub-Model

The output of the Corporate Goal Adjustment Sub-Model is a determination of the level of appropriations in support of corporate administrative and IR&D expenses to be levied on the project manager's operation. Also, a decision as to whether to apply cash flow pressure on the project manager is reached.

PM Goal Adjustment Sub-Model

The PM Goal Adjustment Sub-Model is responsible for modifying the project manager's personal Backlog and Volume goals based on the success of past and current performances and the existence of pressures from the corporate and DOD levels.

DOD Sub-Model

The DOD Sub-Model monitors progress made on each of the projects awarded to the defense contractor and determines whether schedule or quality pressure should be applied at the project manager and corporate levels.

4.6.2 Solution Sequence

Exhibit 4.5 displays the order in which the various sub-models are solved each time period or iteration of the simulation. All sub-models have several functional categories which collectively describe the work flow during the solution sequence. The sub-models and associated routines are listed below. Each sub-model, except several routines in the Corporate Goal Adjustment Sub-Model (which are solved quarterly), are solved each time period of the simulation.

Each iteration of the simulation begins with solution of the PM Manpower Assignment Sub-Model. This involves the project manager reviewing the operating environment taking note of various pressures and goal achievement. The labor force is then broken down between indirect and direct activities and assigned to specific tasks; either to proposal writing or tc an incomplete project. Decisions are also made concerning hiring or firing. After solution of the PM Manpower Assignment Sub-Model, each project in the project manager's backlog is updated through solution of the Project Update Sub-Model.

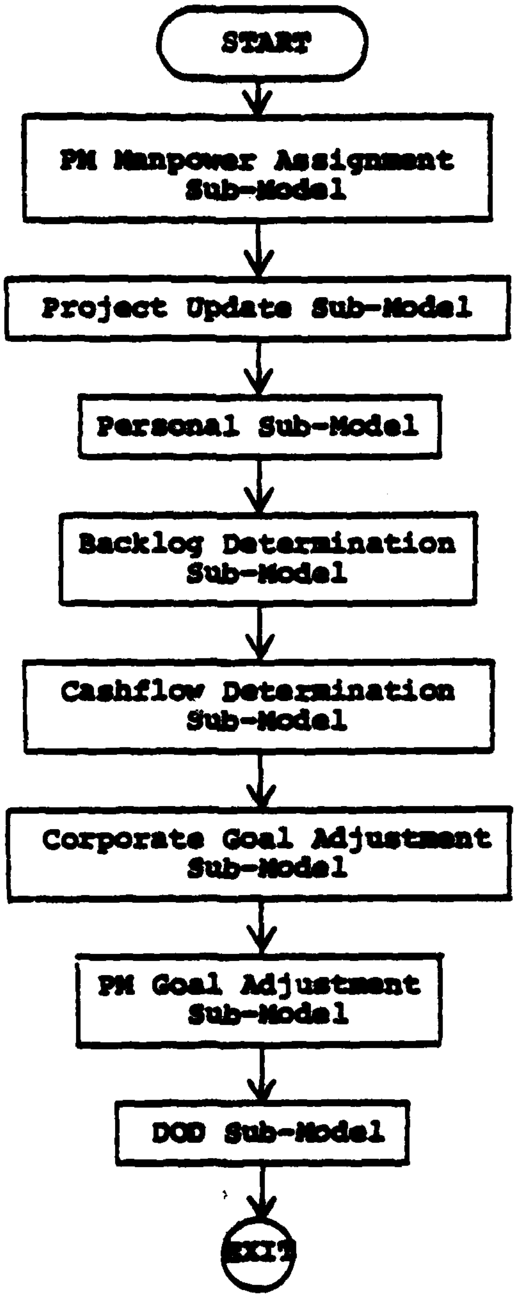
The Personnel Sub-Model is then solved which determines the size and quality composition of the labor force at the end of the period--taking into account the hiring and firing decisions of the project manager and labor force attrition. The Backlog Determination Sub-Model utilizes the output of the Personnel

Sub-Model and calculates the actual months of backlog in the project manager's incomplete project inventory at the end of the period. This also requires determining if a new project has been awarded in the current period.

After solution of the Cash Flow Determination Sub-Model, the Corporate and Project Manager Goal Adjustment Sub-Models are solved. Finally, the DOD Sub-Model which monitors individual project performance is solved.

Exhibit 4.5

Sub-Model Solution Sequence



4.6.3 Sub-Model/Routine Listing

PM Manpower Assignment Sub-Model

a. Goal Achievement and Pressure Check Routine

b. Direct/Indirect Manpower Allocation Routine

c. High/Low Quality Manpower Allocation Routine

d. Project Specific Manpower Assignment Routine

Project Update Sub-Model

a. Schedule Update Routine

b. SQMM Balance Update Routine

c. Dollar Balance Update Routine

d. Quality of Performance Update Routine

Personnel Sub-Model

a. Hiring/Firing Routine

b. Labor Force Attrition Routine

c. Quality of Labor Force Update Routine

Backlog Determination Sub-Model

a. Capture Rate Determination Routine

b. New Proposal Generation Routine

c. New Contracts Awarded Routine

d. New Project Determination and Award Routine

e. New Project Attribute Assignment Routine

f. Accumulation of Existing Projects Routine

g. Backlog Calculation Routine

Cash Flow Determination Sub-Mod

a. Direct Cost Determination Routine

b. Indirect Cost Determination Routine

c. DOD Billing Calculation Routine

d. Cash Flow Calculation Routine

Corporate Goal Adjustment Sub-Model

a. PM Corporate Allocation Routine

b. Corporate Cash Flow Pressure Routine

PM Goal Adjustment Sub-Model

a. Backlog Goal Modification Routine

b. Volume Goal Modification Routine

DOD Sub-Model

a. Schedule Pressure Routine

b. PM Quality Pressure Routine

c. Corporate Quality Pressure Routine

4.7 Conclusion

This chapter has provided a brief introduction to the DPM structure and operating environment. Multiple organizational levels as well as many operational considerations and general behavioral attributes of the model are obviously a direct result of the research findings presented in earlier chapters. In addition, several structural considerations are the result of interview discussions with numerous managerial personnel within defense contracting firms.[5] Examples of these considerations--which are often directly supported by the previously discussed literature on defense contracting organizations and behavior--include the transfer of personnel between direct (billable) and indirect activities as business conditions dictate; acknowledged differences between the quality and technical abilities of individual employees and the transfer of such employees among various projects to resolve specific problems; the attention hierarchy and staffing/backlog concerns of the project manager with proposal writing (and submission to the DOD) recognized as an ongoing activity; the corporate-level concern with cash flow and the DOD concern with performance quality, delivery and cost; and, finally, the autonomous operating environment of the project manager subject to individual project constraints and corporate/DOD pressures.

It should be mentioned that the DPM is not an attempt to model identically the operating environment and procedures of an

actual firm. The research approach instead focuses on the major elements of the defense contracting process as they are perceived to influence contractor behavior and project performance. It is recognized that many important structural considerations identified in the relevant literature and through contractor interviews have been incorporated into the DPM in a simplistic, straightforward manner. This approach is continued in the following chapter with respect to various decision rules and response mechanisms. Despite the lack of congruency between this heuristic modeling methodology and standard models of incentive contract theory, it is felt that the DPM specification is entirely consistent with the appropriate received literature and available knowledge of defense contractor business practices. Furthermore, and most importantly, the validity of this approach is not determined by examination of specific model attributes , but on the simulated behavior of the DPM vis-à-vis real world contracting firms. Examination and hypothesis testing of the simulated output data will be discussed in detail in subsequent chapters.

Footnotes - Chapter 4

[1]Vide, section 3.2, pp.

[2]Richard M. Cyert and James G. March, A Behavioral Theory of the Firm (Englewood Cliffs, N. J.: Prentice-Hall, 1963), p. 151.

[3]DOD quality concerns are assumed to be directed at Major Projects only. See Section 4.3.1.

[4]For simplicity, it is assumed that all types of contracts (e.g., component improvement, concept feasibility studies, etc.) other than large-scale contracts for new weapon systems are included in the Spinoff Project category.

[5]Interviews conducted by Professor Arie Y. Lewin, Duke University, with managerial representatives from several prime defense contractors, September - November, 1980.

CHAPTER 5: MODEL SPECIFICATION

5.1 Introduction

The purpose of this chapter is to provide an in-depth description of each of the various sub-models which comprise the DPM. While the previous chapter discussed the general structure of the model, the focus here will be on specific routines and difference equations. Flow charts are utilized when possible to avoid the complexities of computer coding although a complete listing of the DPM appears in Appendix I.

It is important to caution the reader against viewing the DPM as an assemblage of independent sub-models. While the sub-models are in fact solved recursively (rather than simultaneously), a significant amount of sub-model interaction occurs in the solution process through the use of conditional branching and/or go-to statements. Much of this interaction is not included in the following discussion at it adds little to one's understanding of the simulation process. Nevertheless, the reader should recognize the sub-models as interactive components of the decision process and not stand-alone entities.

5.1.1 Overview

The DPM is designed to simulate the actions of a project manager (PM) in a defense contracting firm and the associated

actions of corporate and DOD management in a dynamic framework. Decisions of the project manager are made on a monthly basis while corporate decisions are made quarterly (except under special circumstances discussed below) after review of the project manager's previous three-month performance. The DOD is concerned with the project manager's actions as they influence project performance only and is able to monitor specific project attributes on a delayed basis. Projects contractually awarded by the DOD are also relevant to the operational concerns of the project manager and corporate-level but, as discussed below, for divergent ulterior motives.

As mentioned in the previous chapter, the contracts awarded by the DOD consist of heterogeneous projects with several distinguishing attributes. Each project is considered either a Major Project or a Spinoff Project with the associated contract awarded in discrete time periods. All contracts contain a dollar budget, delivery date and an amount of standard quality man-months (SQMM) of work to be performed. In addition, Major Projects require that a specific quality standard be achieved before it is considered acceptable for delivery to the DOD.

A primary goal of the project manager is to control the backlog of awarded contracts within maximum and minimum boundaries. There are several mechanisms by which the project manager is able to influence the level of backlog. By increasing the size of the indirect workforce the project manager is able to

increase the dollar value of proposals submitted to the DOD. Likewise, by improving the quality of personnel working on indirect, the quality and capture rate of proposals written in that period increases. The volume and quality of new proposals, in addition to contractor performance on previous projects, will influence the subsequent awarding of new contracts by the DOD.

A secondary but related personal concern of the project manager centers around the maintenance and growth of the technical staff under his responsibility. The workforce consists of high and low quality personnel that are distinguishable to the project manager. Limits exist on the availability of high quality personnel but low quality workers may be hired as necessary to fulfill labor requirements. Higher attrition rates and salary rates are associated with high quality personnel. In general, the project manager pursues, subject to various operational constraints and pressures (discussed below), the attainment of personal backlog and volume (staffing) goals by implementing workforce assignment and hiring/firing decisions on a monthly basis.

The corporate level is concerned primarily with the cash flow performance of the project manager's organization. If this is deemed unsatisfactory (based on the previous three-month cumulative cash flow), pressure is applied on the project manager to improve performance. In order to improve cash flow

performance, the project manager may increase the amount of billable time charged against existing contracts (i.e., increase the number of workers on direct) and/or decrease current cash expenses (i.e., implement firing decisions). An additional concern of corporate is the level of allocations in support of IR&D and administrative expenses levied on the project manager's organization. Expected allocations are increased during prolonged periods of favorable cash flow performance.

The DOD monitors the performance of the project manager on individual projects. Specifically, the DOD is concerned with total costs (as reflected in cumulative billings), delivery and performance quality. The exhaustion of the SQMM balance does not necessarily coincide with that of the dollar project budget. Excess costs incurred on a given project are not fully billable to the DOD, dependent on the contract-type utilized.[1] The DOD is also concerned with the completion of the project by the contractually agreed-upon delivery date. If projects are not completed at this time, pressure is applied on the project manager to expedite delivery (i.e., increase the size of the applicable direct workforce). Finally, a primary concern of the DOD is the quality performance of the Major Project. If the quality of work is determined to be less than the contractually specified minimum level, pressure is applied on the project manager to improve performance quality (i.e., increase the quality of personnel working on the project). If project manager pressue does not result in improved project

quality, the DOD may apply pressure at the corporate level.

5.1.2 General Concepts

It will be helpful at this point to briefly review several important concepts utilized by the DPM as they relate to the theoretical model presented in Chapter 3. Various elements and mechanisms of the decision process environment from the perspective of a sub-coalition manager were previously discussed in Section 3.4. Sub-coalition managers are analogous to decision makers operating at the project manager, corporate and DOD organizational levels. Each decision center pursues the achievement of distinct operational goals and behaves in an autonomous fashion so long as aspiration-levels are satisfied. However, when problems develop and are identified (based on feedback data), conflict between organizational decision centers occurs. Attempts are made by responsible decision makers to alter the state of the system by the transmission of pressure to the appropriate decision center(s). Priority rankings of various operational concerns are established (via attention rules) and decision variables modified (via decision rules) based on standard operating procedures. If standard operating procedures are deemed ineffective, search for new solutions is undertaken and standard decision alternatives are modified (via search rules). Finally, aspiration-level operational objectives of the various decision centers are modified based on prolonged achievement or failure.

5.1.3 Method of Analysis

As previously mentioned, the DPM is not designed to be an exact representation of a 'real-world' firm. It is though, however, that the model as specified provides a reasonable representation of the weapons acquisition environment and 'real-world' defense contractor benavior. Throughout the DPM heuristic decision rules have been hypothesized based on our general accumulated knowledge of defense contractor business practices. These behavioral components, described in the following sections, are decoupled and parameterized in order to facilitate 'fine-tuning'--or more extensive structural changes--as deemed necessary by future research findings. However, because a large portion of the model specification is directly justified by the received literature and/or numerous interview discussions with DOD/contractor management personnel,[2] it is felt with confidence that few substantice components of the DPM are seriously deficient.

5.2 PM Manpower Assignment Sub-Model

The PM Manpower Assignment Sub-Model, as shown in Exhibit 5.1, consists of four major routines: the Goal Achievement and Pressure Check; Direct/Indirect Manpower Allocation, High/Low Manpower Allocation and, finally, the Project Specific Manpower Assignment Routine. Because of the importance and complexity of these routines, each is discussed in detail below.

Exhibit 5.1

PM Manpower Assignment Sub-Model

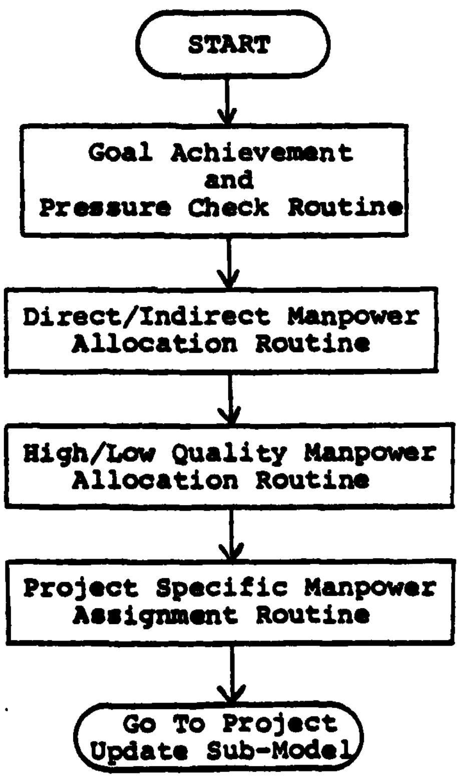
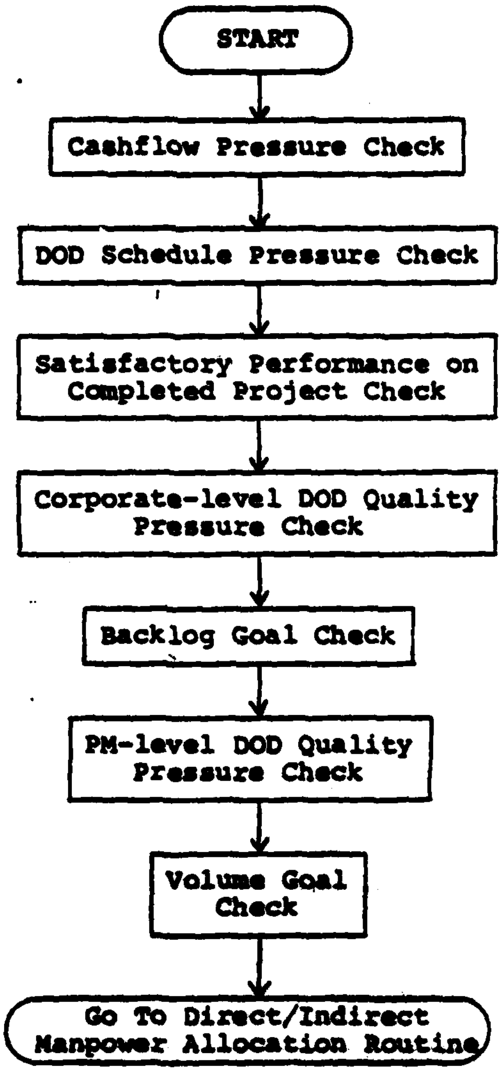


Exhibit 5.2

Goal Achievement & Pressure Check Routine



5.2.1 Goal Achievement and Pressure Check Routine

The Goal Achievement and Pressure Check Routine combined with individual project constraints provide the basis of all decisions made by the project manager. As demonstrated in Exhibit 5.2, the project manager will initially determine if Corporate Cash Flow or DOD Schedule Pressures are being applied followed by a check to see if completed major projects are below the minimum quality standard.

The project manager then determines if Corporate DOD Quality Pressure is being applied and if current backlog is within acceptable boundaries. Finally, the existence of Project Manager DOD Quality Pressure is checked and the current size of the operation is compared with the project manager's Volume (staff) Goal.

5.2.2 Direct/Indirect Manpower Allocation Routine

The breakdown of the labor force in the Direct/Indirect Manpower Allocation Routine is determined by the results of the Goal Achievement and Pressure Check Routine--specifically, the Cash Flow Pressure and Backlog Achievement checks. As shown in Exhibit 5.3, if Cash Flow Pressure is being applied and the current backlog is low, the project manager will not alter the existing breakdown of the workforce between direct and indirect activities. If the backlog is not low, however, the project manager will increase the proportion working on direct (billable)

activities in response to the Cash Flow Pressure. The project manager's upward adjustment of the proportion of the workforce on direct activities, PD, is described by the following function:

$$PD_t = PD_{t-1} + \alpha_d . (1-PD_{t-1}),$$

where α_d is the constant adjustment parameter equal to .10 and the initial value of PD in period 0 is .80.

If the project manager's current backlog exceeds the maximum acceptable level, the proportion of labor working direct is increased using a slightly modified function:

$$PD_t = PD_{t-1} + (2.\alpha_d) . (1-PD_{t-1}).$$

This allows the project manager to more quickly increase PD, and therefore billable time, wnen under Cash Flow Pressure. This initial number of months of backlog and the upper and lower acceptable boundaries are 15, 12 and 18, respectively.

When no Cash Flow Pressure is being applied and the backlog is below the minimum desired level, the project manager will increase the proportion of his workforce on indirect (proposal writing) activities. The upward adjustment of the proportion of the workforce on indirect activities, PI, is described by

$$PI_t = PI_{t-1} + \alpha_i(1-PI_{t-1}),$$

where α_i is the adjustment parameter equal to .05 and the initial value of PI in period 0 is .20. This action will increase

Exhibit 5.3

Direct/Indirect Manpower Allocation Routine

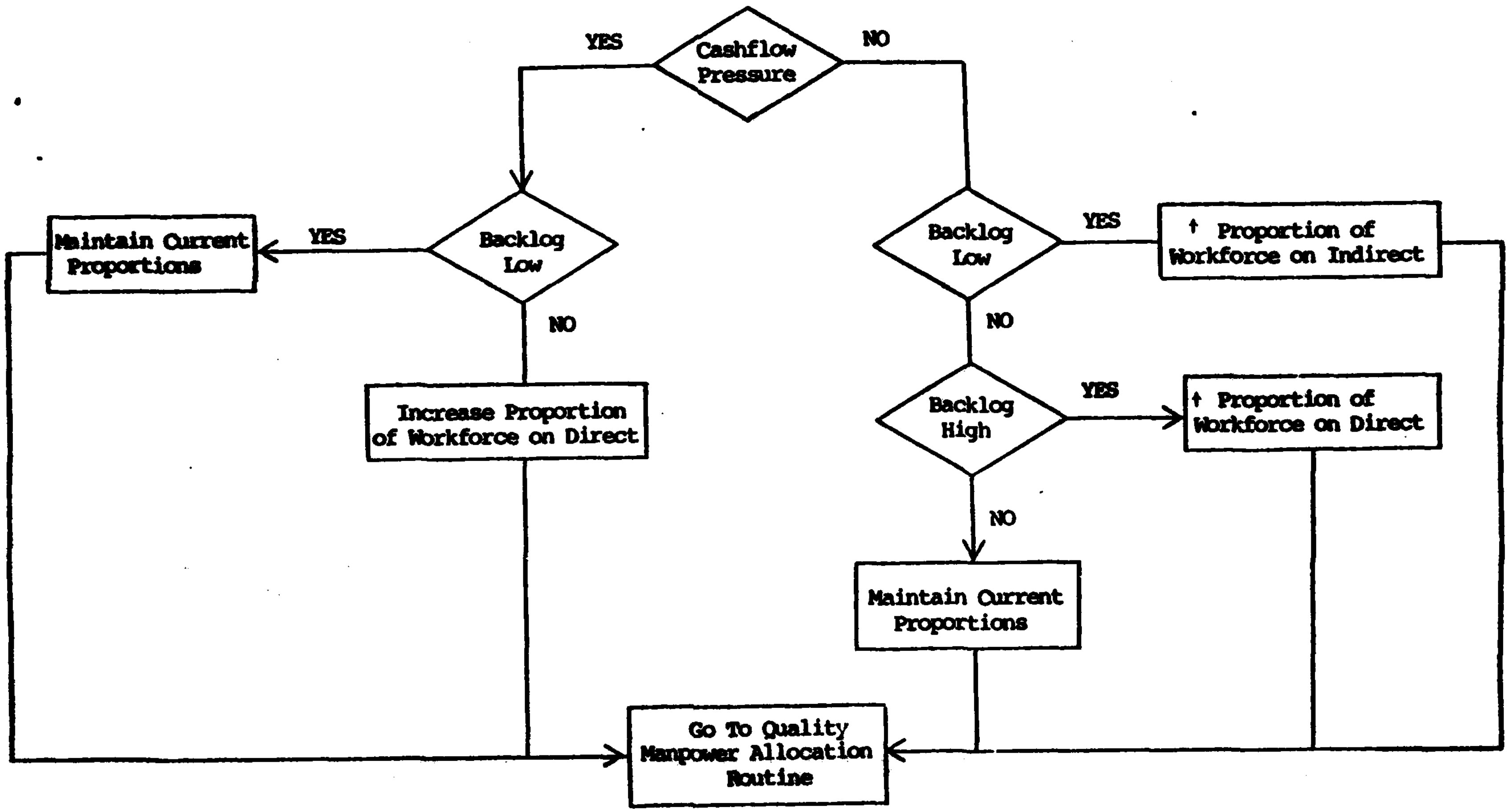
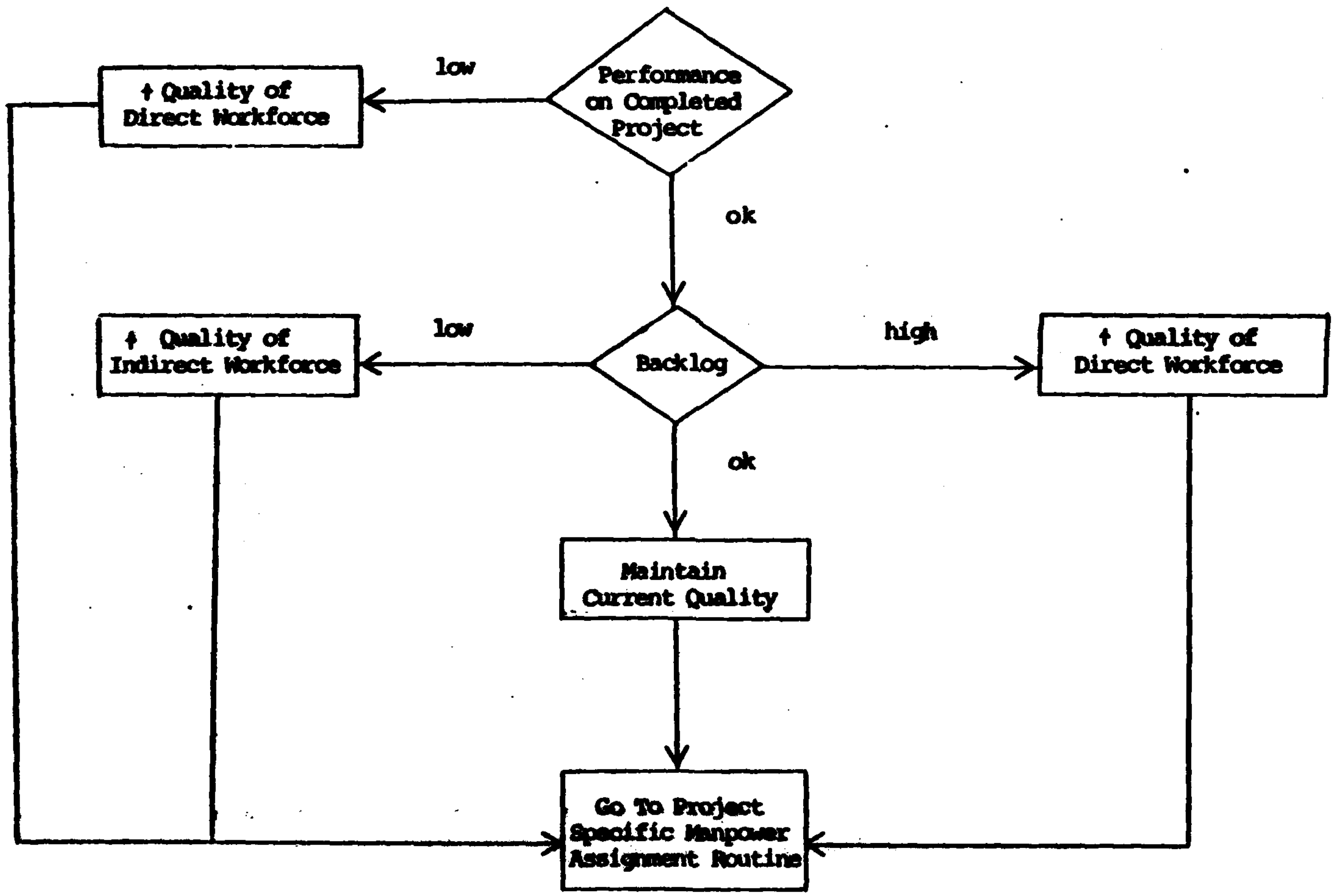


Exhibit 5.4

High/Low Quality Manpower Allocation Review



the dollar volume of proposals submitted to the DOD. On the other hand, if the current level of backlog is above the maximum desired level, the project manager will increase the direct workforce in order to work the backlog down to an acceptable level. Finally, no changes will be made in direct/indirect manpower allocation if the backlog is within boundaries and Cash Flow Pressure is not being applied.

5.2.3 High/Low Quality Manpower Allocation Routine

If a Major Project is otherwise complete except for a deficient quality performance, additional high quality work is required to be performed. As demonstrated in Exhibit 6.4, when this situation confronts the project manager, the quality of the direct workforce will be improved, regardless of other pressures or goals. When this situation is not the case, Backlog Goal satisfaction becomes the determining factor in quality allocation decisions.

The mechanism by which quality adjustments are assumed to take place will be described using an increase in direct labor quality as an example. The adjustment for indirect labor quality is analogous. The quality of labor working direct is improved by increasing the proportion of high quality personnel working on direct activities, PHD, using the following adjustment mechanism:

$$PHD_t = PHD_{t-1} + \beta_{hd} \cdot (PH_t - PHD_{t-1}),$$

where β_{hd} is the adjustment parameter equal to .20 (β_{hi} = .15) and PH is the proportion of the total workforce considered high quality. Initial values of PHD (PHI) and PH are .20 (.05) and .25, respectively. Note that the functional form prevents PHD (PHI) from exceeding PH.

During each time period of the simulation, the quality of the direct (indirect) workforce DQ (IQ) is calculated using the following function:

$$DQ_t = [(HQ^{HDL_t}).(LQ^{LDL_t})]^{(DL_t)^{-1}},$$

where HQ and LQ are the quality indices of high and low quality workers equal to 1.25 and .8, respectively. The initial number of high and low quality workers assigned to direct (indirect) activities are signified by HDL and LDL (HIL and LIL) with initial values of 20 and 60 (5 and 15), respectively. Note that the function utilized is in the form of a geometric average; thus DQ will always be between 1.25 and .8.

If the project manager's current backlog is below the minimum acceptable level, the quality of the indirect workforce will be increased. This will increase the desirability of proposals submitted to the DOD that period. Conversely, if the backlog is high the quality of the direct workforce will be increased as new projects are no longer necessary. Finally, no quality adjustments are made if the current backlog is considered satisfactory by the project manager.

5.2.4 Project Specific Manpower Assignment Routine

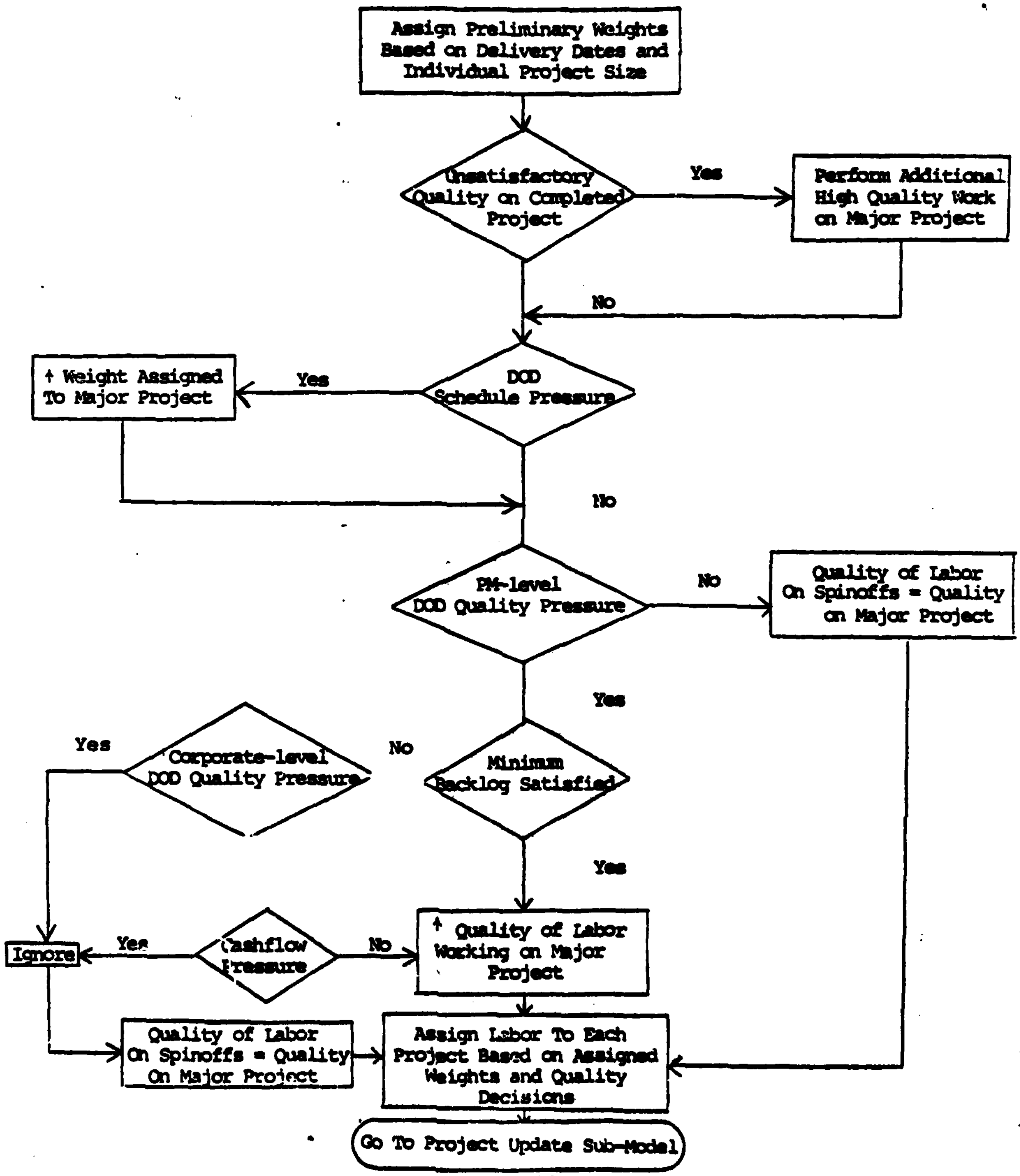
The final labor force allocation decision of the project manager requires the assignment of the direct labor force to specific projects. This involves a determination of the quality as well as the number of workers to assign to each project. Exhibit 5.5 demonstrates how the Project Specific Manpower Assignment Routine performs this task.

Preliminary weights are assigned to each project dependent on the volume of work remaining to be done (SQMM's) and the delivery date--assuming the quality of work performed on all projects will be equal. The project manager then checks to see if the quality of work performed on an otherwise completed project is unsatisfactory and, if so, will perform additional high quality work on that project. The project manager will increase the weights of a tardy project as signified by DOD Schedule Pressure.

If no PM DOD Quality Pressure has been applied, the quality of work on all projects will be equivalent. If PM DOD Quality Pressure is being applied and the project manager's minimum backlog goal is currently being satisfied, the quality of work performed on the Major Project will be improved. If the current backlog is low, however, the project manager will ignore the PM DOD Quality Pressure and all project quality will be equal--unless there is Corporate DOD Quality Pressure being applied. If Corporate DOD Quality Pressure is being applied and the current period is void of Corporate Cash Flow Pressure, the

Exhibit 5.5

<u>Project Specific Manpower Assignment Routine</u>



project manager will improve the quality of work performed on the Major Project. When Corporate Cash Flow Pressure is being applied, all DOD quality pressures will be ignored.

Finally, the project manager is able to assign workers to individual projects based on the weights and quality decisions made above.

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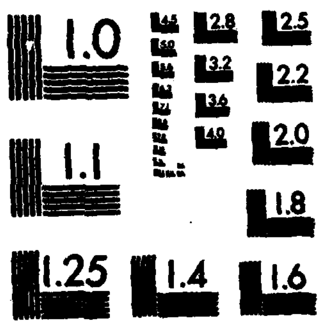


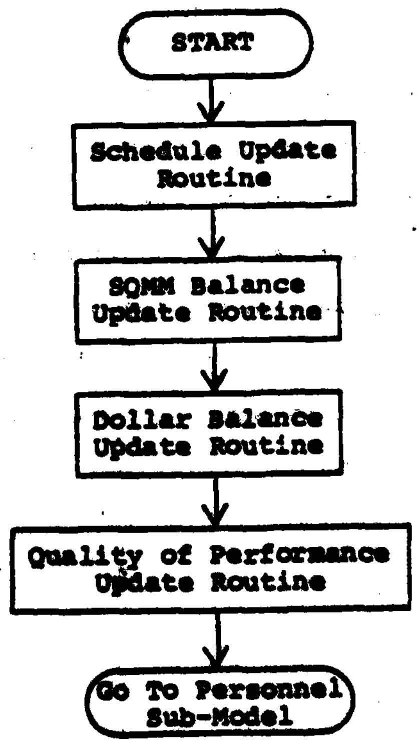
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

5.3 Project Update Sub-Model

Exhibit 5.6 demonstrates the four routines in the Project Update Sub-Model: Schedule Update, SQMM Balance Update, Dollar Balance Update and Quality of Performance Update. The Project Update Sub-Model serves a bookkeeping function for each of the projects in the project manager's backlog. While the output of this sub-model is basic to the realistic functioning of the DPM, the logic flow is straightforward and mechanical and therefore not discussed. See Appendix 1 for the specific details.

Exhibit 5.6

Project Update Sub-Model

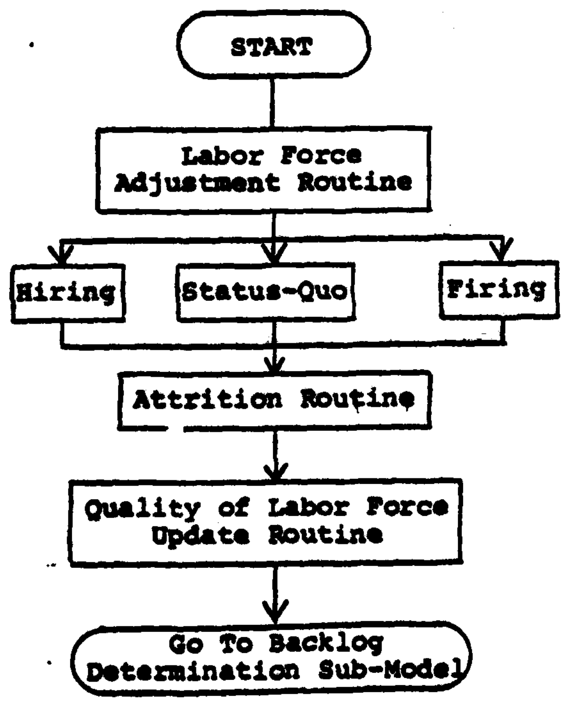


5.4 Personnel Sub-Model

The Personnel Sub-Model determines the end-of-the-month labor force composition based on the project manager's hiring/firing status-quo decisions and the attrition rate. These functions are shown in Exhibit 5.7 and will be discussed further below. It should be noted that the project manager is unable to compensate for attrition in the current month. Therefore, the project manager's desired workforce size is not necessarily achieved in the subsequent period based on implementation of current decisions concerning labor force modification.

Exhibit 5.7

Personnel Sub-Model



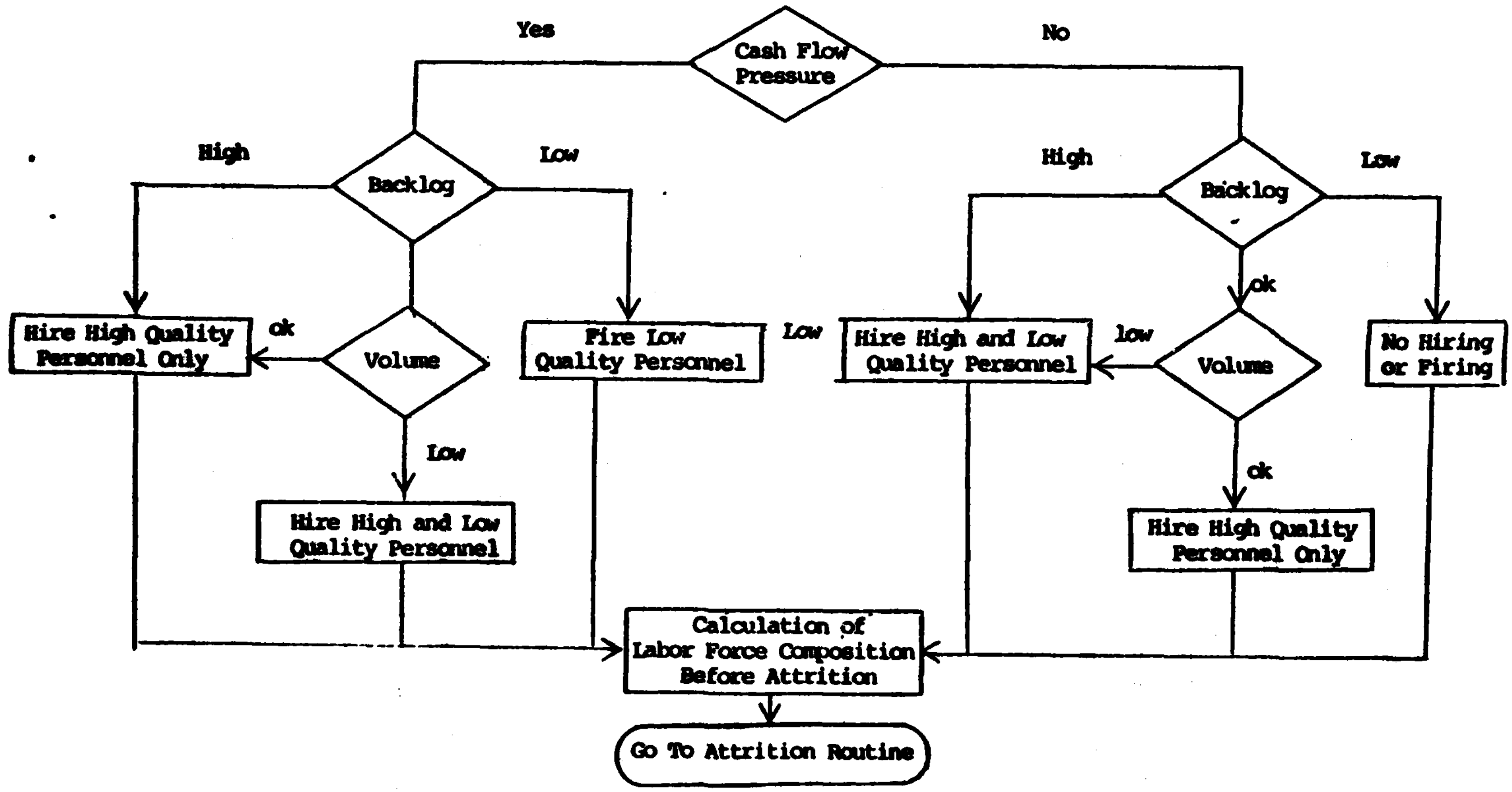
5.4.1 Labor Force Adjustment Routine

Decisions to actively modify the size of the workforce are a function of Corporate Cash Flow Pressure and the attainment of the project manager's personal Backlog and Volume Goals (see Exhibit 5.8). If Corporate Cash Flow Pressure is being applied and the project manager's backlog is below the minimum acceptable level, firing of low quality personnel will occur. If the current backlog is too high (or if both the backlog and volume levels are satisfactory), the project manager will hire high quality personnel only. Finally, if the backlog is satisfactory but the volume goal is not being satisfied, the project manager will make a general hiring decision which results in the hiring of high and low quality workers.

If no Corporate Cash Flow Pressure is being applied, the project manager will make a general hiring decision when the backlog is high or if it is within bounds and the current volume is low. If the current levels of backlog and volume are within bounds, the project manager will hire just the few high quality workers that are available (i.e., no low quality). Finally, if the backlog is below the minimum acceptable level, the project manager will hire neither high nor low quality workers.

Exhibit 5.8

Labor Force Adjustment Routine



The general hiring decision is described by the following mechanism:

$$LAB_{t+1} = (1+\alpha).LAB_t$$

where LAB is the size of the workforce with an initial value of 100 and α is the adjustment mechanism equal to .03. Likewise, if a firing decision is made, low quality workers, LLAB, are reduced by

$$LLAB_{t+1} = (1-\alpha).LLAB_t.$$

If the project manager desires to hire only high quality workers HLAB, adjustments are made as follows:

$$HLAB_{t+1} = (1+\alpha_h).HLAB_t$$

where $\alpha_h = .01$.

5.4.2 Attrition and Quality of Labor Force Update Routines

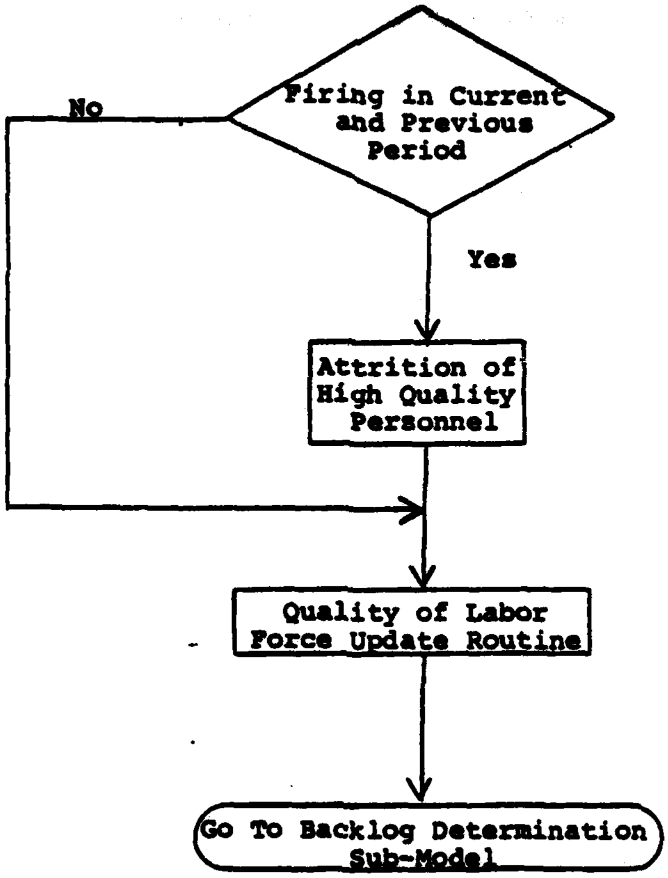
It is assumed that if the project manager's operation is in a downturn such that prolonged firing has occurred (i.e., two or more consecutive periods), attrition of high quality personnel will occur as follows:

$$HLAB_{t+1} = (1-\lambda_h).LAB_t$$

where $\lambda_h = .02$. At no time will attrition of low quality personnel occur (see Exhibit 6.9). The final routine of the sub-

Exhibit 5.9

Attrition and Quality of Labor Force Update Routines



model is the determination of the size and quality of the end-of-the-period labor force dependent on the output of the previous routines.

5.5 Backlog Determination Sub-Model

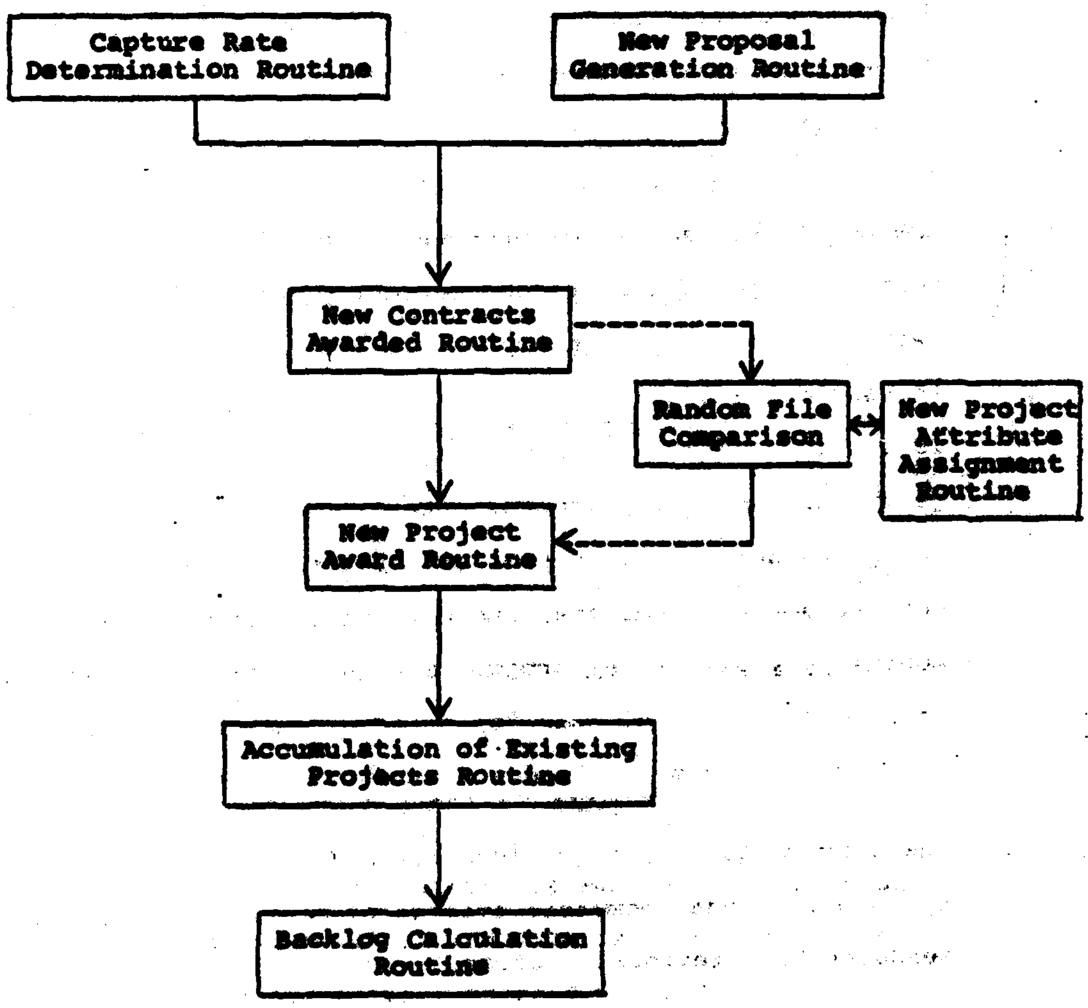
The Backlog Determination Sub-Model, as illustrated in Exhibit 5.10, consists of seven routines: Capture Rate Determination, New Proposal Generation, New Contracts, New Project Determination and Award, New Project Attribute Assignment, Existing Project Accumulation and, finally, the Backlog Calculation. The capture rate of proposals submitted to the DOD is a function of the quality and variance of past performance and the quality of the written proposal. The product of the capture rate and the dollar volume of new proposals provides the amount of awarded contracts that accure to the current period. Once the accrued awards accumulate to an amount greater than a randomized threshold, a project equal in size to the accumulated accruals is assigned to the project manager's backlog. Remaining project attributes are also assigned at this point. Finally, the remaining dollar balances of all current and newly awarded contracts are accumulated and divided by the fully burdened monthly payroll of the project manager, thus providing the backlog calculation. The following discussion will describe the various steps involved with this calculation.

The average quality of performance AVEQ is first calculated by computing the geometric average of previous direct quality measures DQ (previously defined):

$$AVEQ_t = (DQ_{t-12})^{.1} * (DQ_{t-11})^{.1} * \cdot \cdot \cdot * (DQ_{t-3})^{.1}.$$

Exhibit 5.10

Backlog Determination Sub-Model



The variance of the quality of past work performed VARQ is then computed over the same time periods

$$\mathrm{VARQ}_t = \sum_{n=3}^{12} (\mathrm{AVE}_t - \mathrm{DQ}_{t-n})^2 .$$

Using the average and variance of work quality measures, the overall quality of past performance QPERF is calculated as

$$\mathrm{QPERF} = \beta(\mathrm{AVEQ}^{\beta_1} \cdot \mathrm{VARQ}^{\beta_2}),$$

where $\beta = .25$, $\beta_1 = 1.25$, and $\beta_2 = -.25$.

Note that a single measure of past performance has been calculated which considers both the average and variance of past quality. As shown above, when the average quality of work performed is improved, QPERF is favorably influenced. However, when the variance of past performance is increased, QPERF is decreased in magnitude. This reflects the adverse desirability of variable quality performance to the DOD. The QPERF measure, to a large extent, will determine the success rate of capturing new contracts.

The capture rate is now calculated as a function of the quality of past performance and the quality of the submitted proposal, IQ. As earlier discussed, the quality of proposals is analogous to the quality of the indirect workforce. The capture rate CAPTR is defined using the following logit functional

form (which constrains the resultant value to be between 0 and 1):

$$CAPTR = [1+e^{(\alpha_1+\alpha_2 \cdot IQ_{t-3}+\alpha_3 \cdot QPERF)}]^{-1},$$

where $\alpha_1 = -4$

$\alpha_2 = 2.5$, and

$\alpha_3 = 1.5$.

The dollar value of new proposals written during each period NEWPR is a multiplicative function of the number of indirect workers IL, the quality of workers IQ, the monthly salary of a worker SAL, and a proposal multiplier PRPM, or

$$NEWPR = IL * IQ * SAL * PRPM,$$

where the constant values of SAL and PRPM are \$3,000 and 7, respectively, and the initial value of IL = 20. The dollar value of newly awarded contracts NEWCONTR which accure to the current period is the product of CAPTR and proposals submitted two months earlier, or

$$NEWCONTR = CAPTR * NEWCONTR_{t-2}.$$

In order to determine if a contract is awarded in the current period the cumulative value of NEWCONTR is compared to a random file (uniformally distributed between \$.5 and \$1.5, a mean \$1 million). When this threshold is exceeded, a new contract is awarded with the dollar magnitude equal to the sum of the

previous accruals, OUTCONTR. The following relationship is used to assign the required amount of SQMM's to the newly awarded project, TPROJSQMM:

$$TPROJSQMM = \frac{OUTCONTR}{(PH*HQUAL*HSALRATE)+(PL*LQUAL*LSALRATE)} * \frac{1}{(1+NEGOH)*1.1},$$

where HQUAL = 1.2,

LQUAL = .8,

HSALRATE = 3.33,

LSALRATE = 2.77, and

NEGOH = 1.

Finally, the duration of the newly awarded contract is determined by the following function:

$$DURATION = \alpha_1 + \beta[1 + e^{-(\alpha_2*NEWCONTR)}]^{-1},$$

where $\alpha_1 = 3$,

$\beta = 15$, and

$\alpha_2 = .01$.

This functional form constrains the project duration to be between 3 and 18 months, depending on the size of the awarded contract.

5.6 Cash Flow Sub-Model

The Cash Flow Sub-Model serves as a bookkeeping function in the DPM by calculating the cumulative, annual and monthly cash flows of the project manager's organization (see Exhibit . The cumulative cash flow from the previous period determines whether the firm is able to invest in short-term securities STINV or required to borrow short-term funds STLOAN.

The cumulative allowable project fee is calculated as 10% of total budget billings (fully burdened), or

FEE = .10 * DL * DSAL * (1 + NEGOH)

where DSAL is the average salary rate of the direct workforce (which is dependent on the quality composition) and NEGOH is the negotiated overhead rate equal to 100%.

The corporate administrative expense ADMIN is also a percent of direct billings (unburdened) PERCTAD,

ADMIN = PERCTAD * DL * SAL.

Corporate IR&D expense CIRD is a constant 13.5% of direct unburdened billings corporate fixed expenses FIX (equal to $50,000).

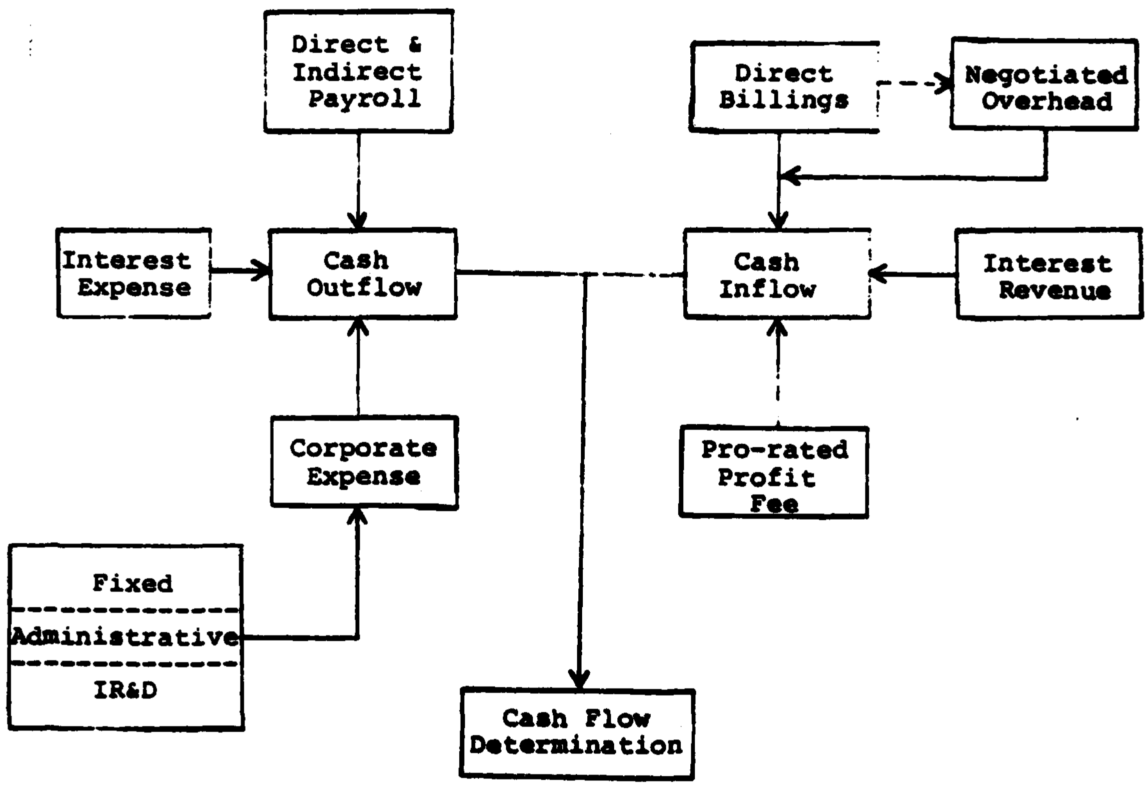
Finally, the cash outflow and inflow may be calculated:

OUTFLOW = (FIX + CIRD + ADMIN + DLAB * DSAL + ILAB * ISAL + [STLOAN (INT + .03) ÷ 12], and

INFLOW = (1+NEGOH) * DSAL * DLAB + [(INT * STINV) ÷ 12] + [(.8 * FEE) ÷ 12],

Exhibit 5.11

Cash Flow Determination Sub-Model



where INT is the annual interest rate equal to 15% and assuming that a maximum of 80% of the FEE will be collected.

5.7 Corporate Goal Adjustment Sub-Model

The Corporate Goal Adjustment Sub-Model is solved on a quarterly basis unless cash flow pressure is currently being applied on the project manager. As illustrated in Exhibit 5.12, if the decision is made by corporate to apply pressure, the cash flow performance is automatically monitored the next two months to see if the previous six months cumulative cash flow is positive. If this is the case, signifying to corporate that the poor current cash flow performance is likely to be temporary, pressure is removed.

When cash flow of the previous quarter is negative, corporate pressure is applied and allocations in support of corporate administrative are reduced by 5% relative to the previous allocation. Conversely, when cash flow is positive pressure is not applied and allocations are increased.

5.8 PM Goal Adjustment Sub-Model

The PM Goal Adjustment Sub-Model consists of two routines, the Backlog Goal Modification and Volume Goal Adjustment routines. The former is demonstrated in Exhibit 5.13. When backlog is satisfactory for two successive months, the project manager will increase the maximum and minimum goals by 5%. If cash flow pressure has been applied in either of the previous two months, the goals remain unchanged. If backlog is less than the minimum acceptable level for six successive months, goals are decreased according to the following mechanisms:

$$BACKMIN_{t+1} = BACKLOG_t + [(BACKMIN_t - BACKLOG_t) \div 2],$$

and $$BACKMAX_{t+1} = BACKMIN_{t+1} + 6.$$

In all other cases, the goals are not modified.

As illustrated in Exhibit 5.14, if firing has taken place in the current period, the minimum desired level of staff (Volume) is decreased. If firing has not taken place, backlog is satisfactory and cash flow pressure is absent, the Volume Goal is increased. Any adjustments to the Volume Goal are made in 1% increments relative to the current goal.

Exhibit 5.12

Corporate Goal Adjustment Sub-Model

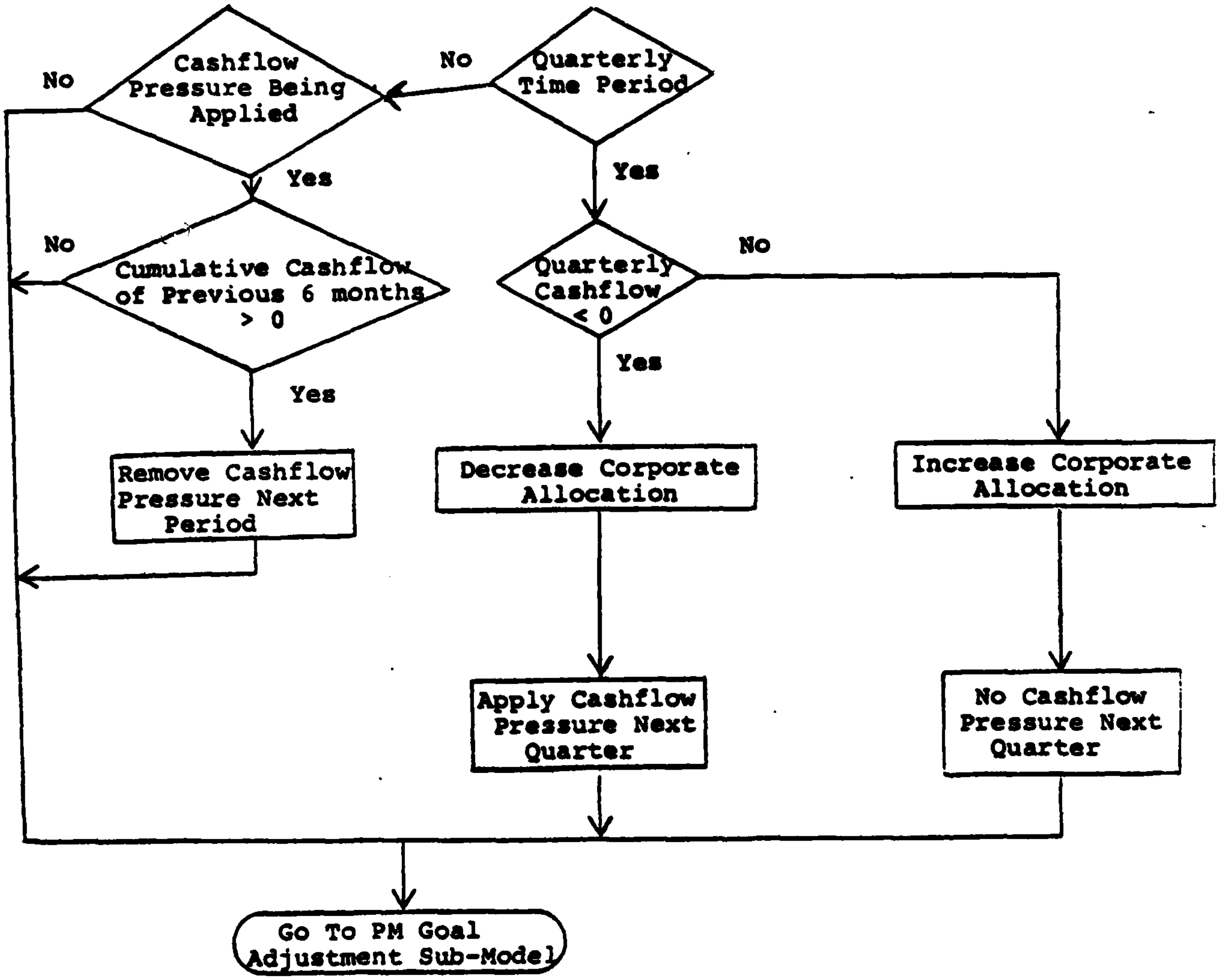


Exhibit 5.13

PM Volume Goal Modification Routine

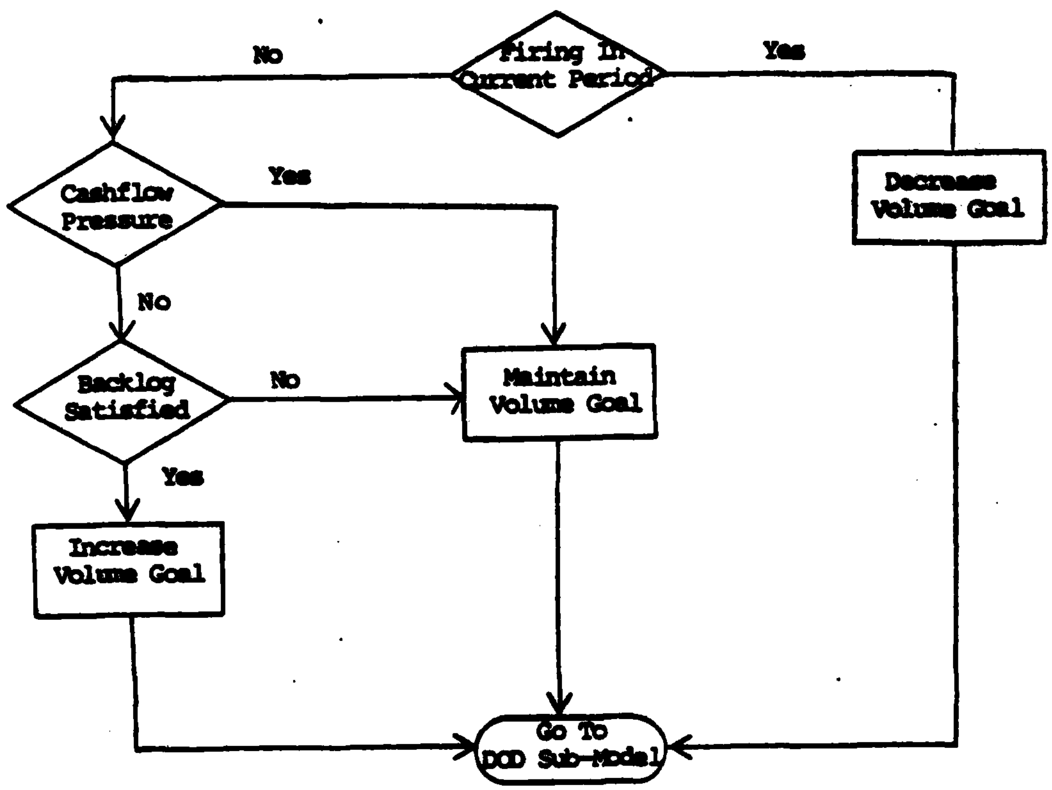
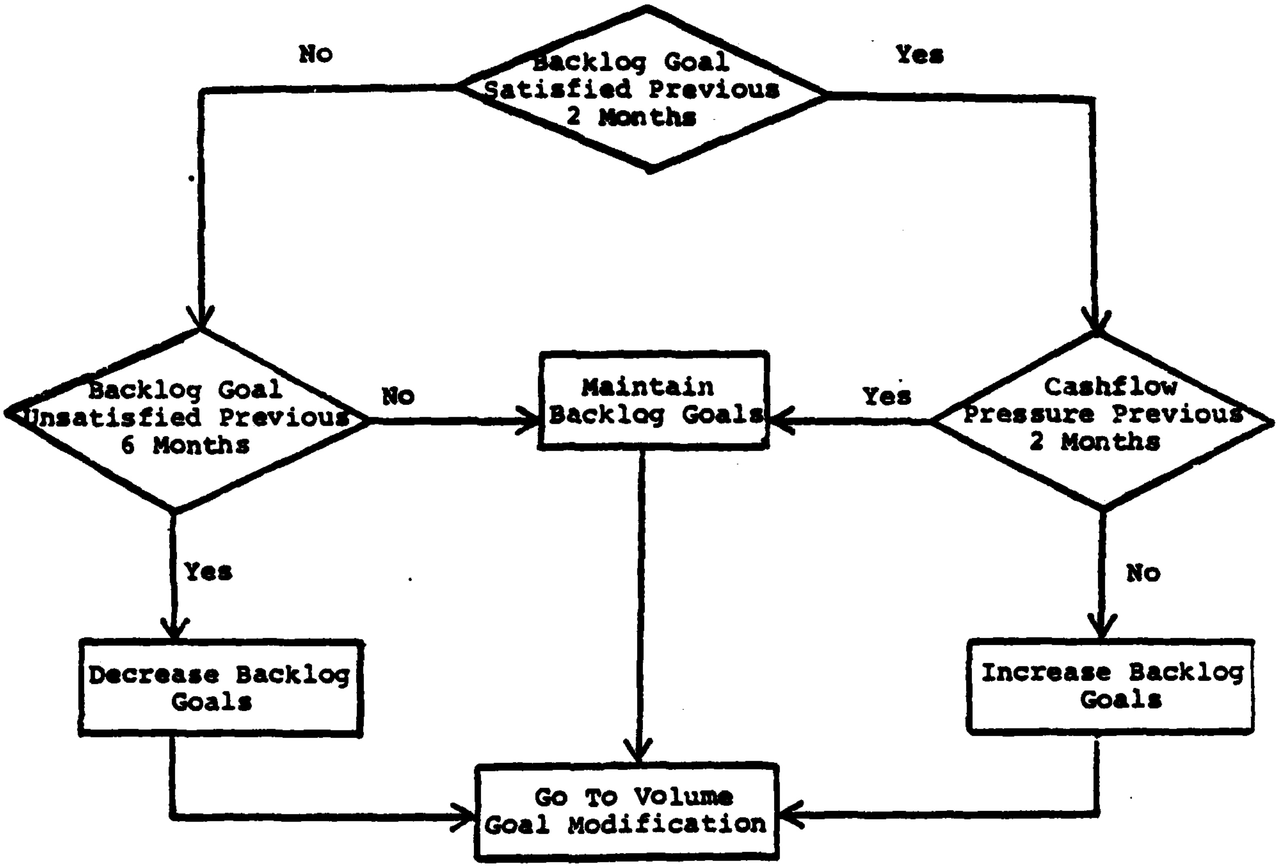


Exhibit 5.14

PM Backlog Goal Modification Routine



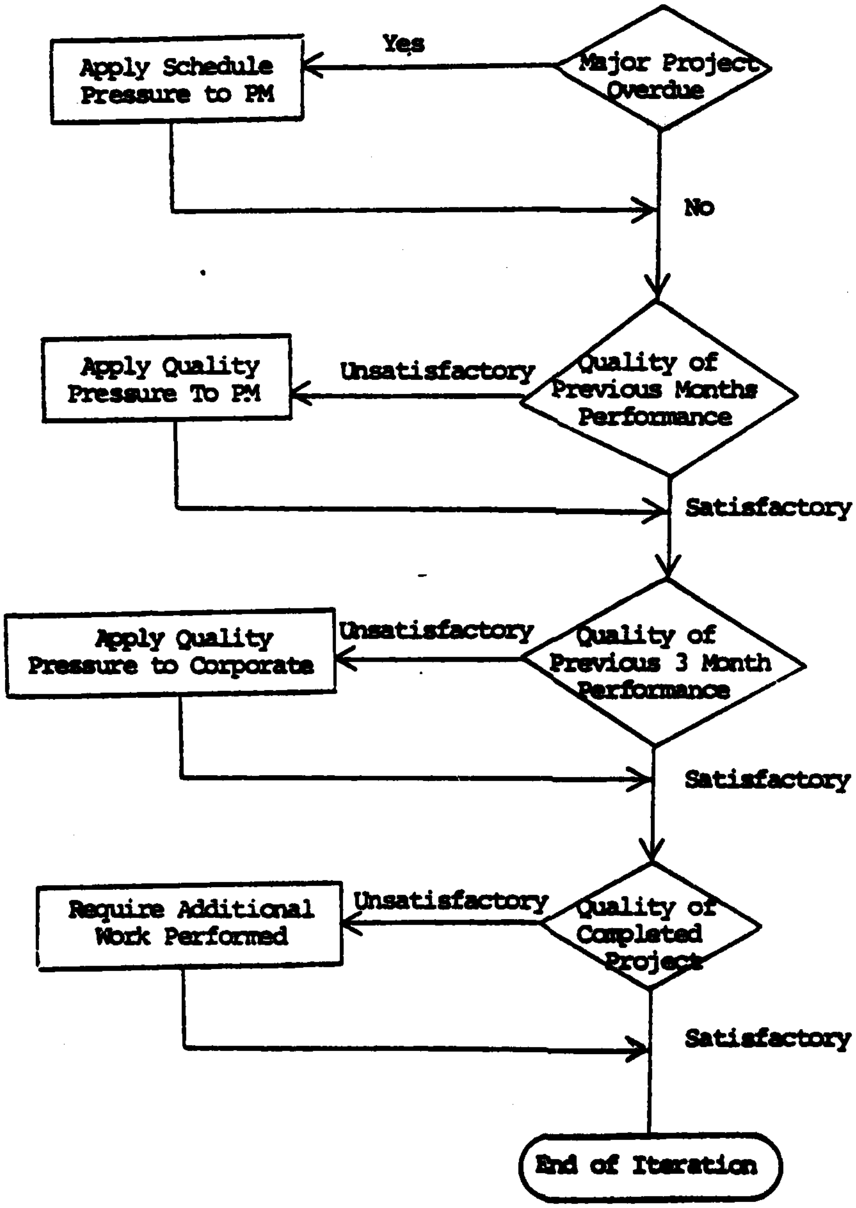
5.9 DOD Sub-Model

The DOD Sub-Model is displayed in Exhibit 5.15. As discussed earlier, the DOD will monitor the project manager's performance on Major Projects and apply pressure to the project manager or Corporate levels as necessary.

Schedule Pressure is applied to the project manager when the Major Project is determined to be overdue. When the quality of work performance on the Major Project is unsatisfactory, the DOD will initially apply pressure on the project manager. If the condition persists, pressure will be applied at the corporate level. Finally, if a project has been completed (i.e. no remaining balance of SQMM's) but the quality of performance is less than the minimum acceptable level, additional work will be required until the overall quality is acceptable.

Exhibit 5.15

DOD Sub-Model



FOOTNOTES - CHAPTER 5

[1]The current version of the DPM analyzes FFP-type contracts only. Research is currently underway to include other basic contract-types in the analysis.

[2]Interviews conducted by Professor Arie Y. Lewin, Duke University, with managerial representatives from several prime defense contractors, September - November, 1980.

CHAPTER 6: SIMULATION RESULTS

6.1 Overview

The objective of this chapter is to present the simulated output of three scenarios which were generated by modifying the underlying assumptions of the DPM. Each scenario's results will be analyzed from the perspective of the project manager, corporate and the DOD by examination of time series plots of key performance and control variables. It will be shown that differences in the simulated output from the various scenarios are consistent with and explained by changes made to the project manager's operating environment.

The DPM was solved over a 72 period horizon or six years of monthly and quarterly decision adjustments. One year or 12 periods of historical data is necessary to initialize the simulation; therefore, time trends of important variables will be shown beginning in period 12. The data base is designed such that the project manager is able to simultaneously evaluate a maximum of 10 separate projects in any given time period. No constraint exists on the number of projects which may be awarded over the course of a simulation.

6.2 Scenario 1: Standard Simulation

Scenario 1 will be considered the standard to which other simulations will be compared. The assumption is made that the

project manager is awarded a Major Project in period 1 and no other Major Projects are assigned throughout the simulation. While no mechanism is currently specified which translates corporate IR&D allocations into Major Projects, the occurrence of a follow-on Major Project is investigated in Scenario 3.

Because the Scenario 1 project manager is not awarded another Major Project, his personal backlog and volume goals (as well as associated corporate and DOD concerns) must be satisfied by the attainment of new spinoff projects and the completion of the initial Major Project.

6.2.1 Project Manager Considerations

As mentioned previously, a primary goal of the project manager is to control his backlog within maximum and minimum boundaries. Exhibit 6.1 displays the level of backlog (B) with the upper (H) and lower (L) boundaries. While the project manager is fairly successful in maintaining the backlog above the minimum acceptable level, there are clearly several periods, particularly in the early and later periods of the simulation, where adjustments were necessary.

There are several mechanisms by which the project manager is able to control his level of backlog. Perhaps the most direct is increasing the volume of new proposals submitted to the DOD. This is, of course, influenced by the size of the indirect work force. Exhibit 6.2 demonstrates this relationship where the

Exhibit 6.1

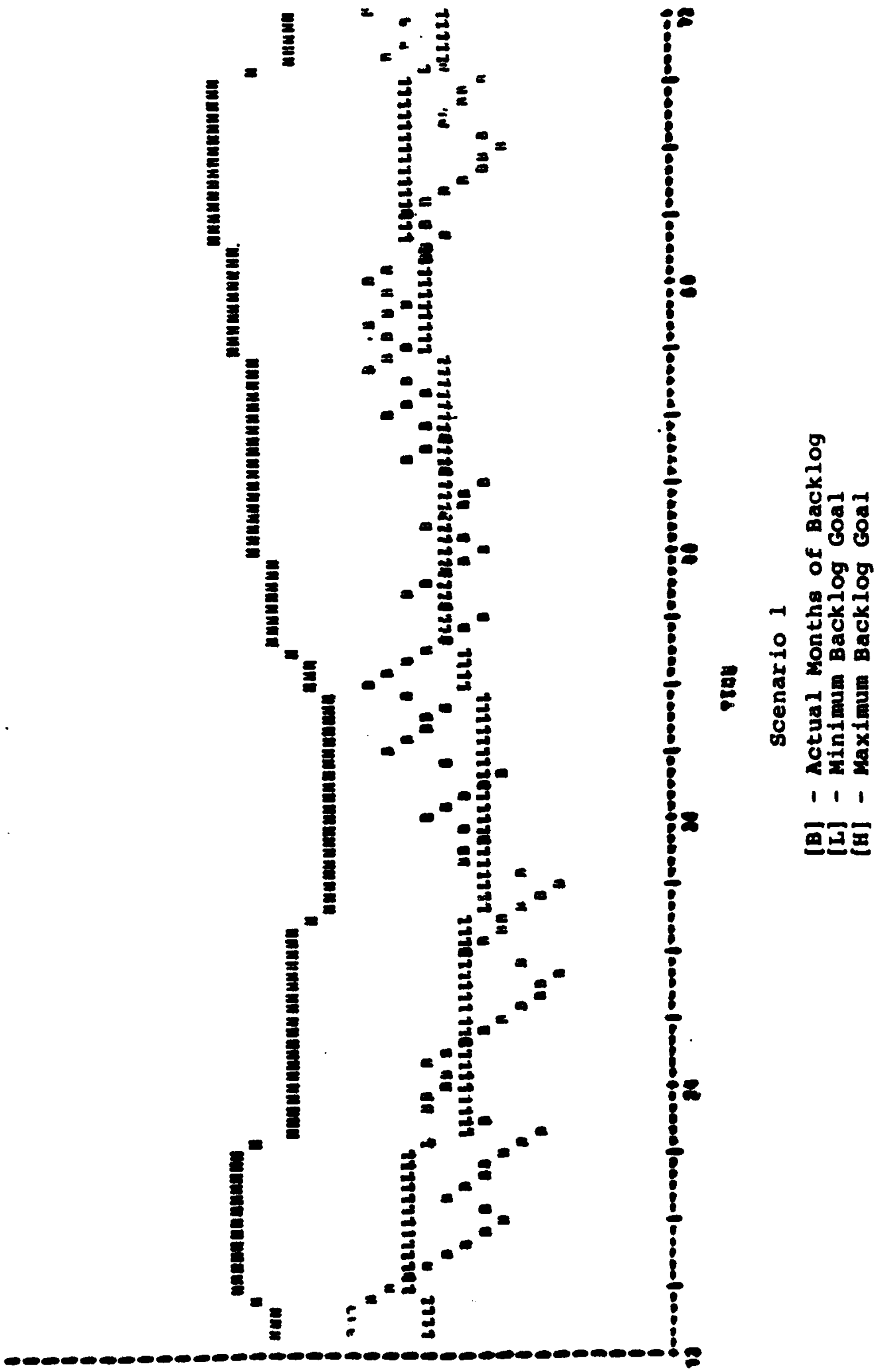
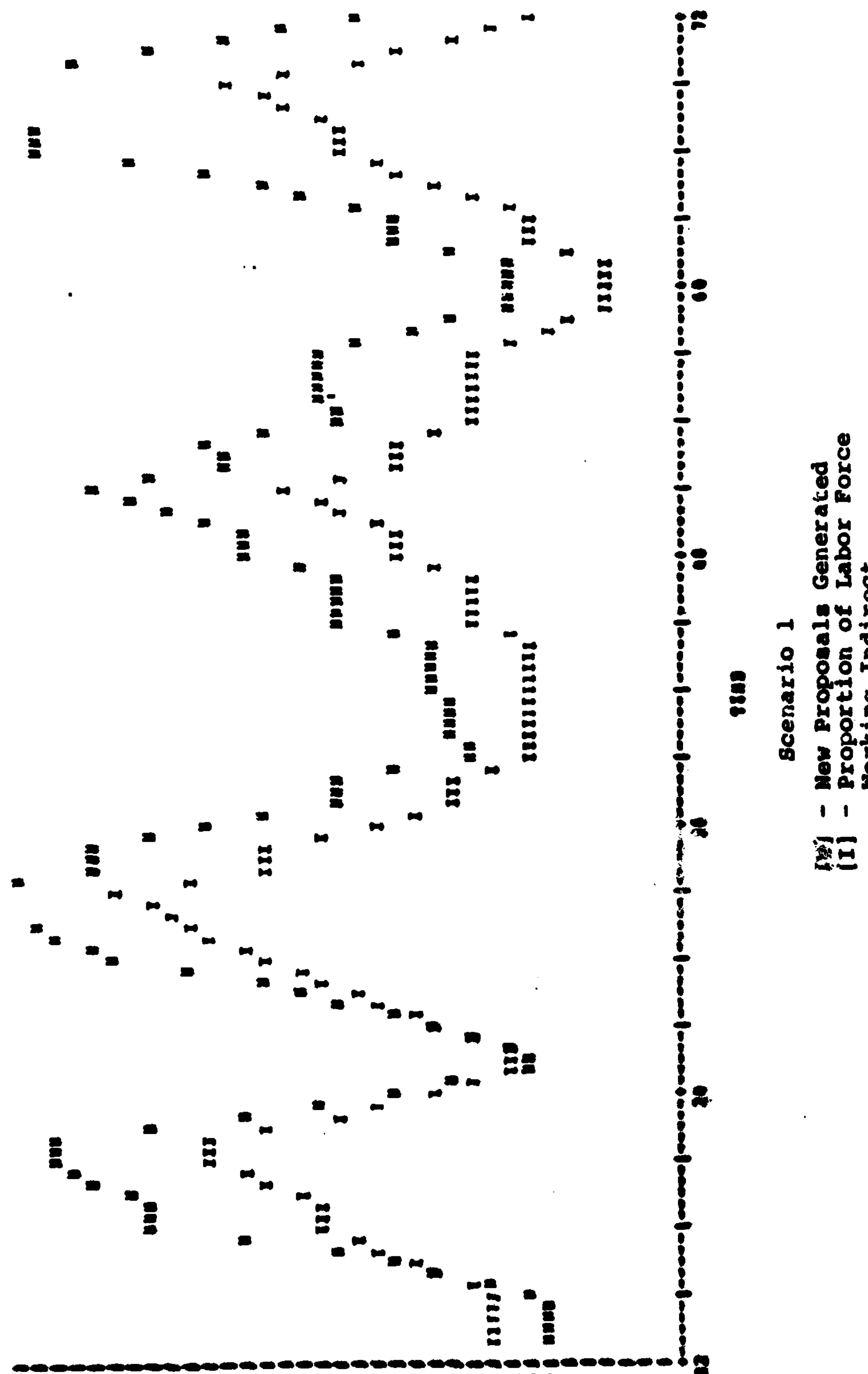

Scenario 1
[B] - Actual Months of Backlog
[L] - Minimum Backlog Goal
[H] - Maximum Backlog Goal

Exhibit 6.2


Scenario 1
[N] - New Proposals Generated
[I] - Proportion of Labor Force
Working Indirect

volume of new proposals, "N", follows very closely the plot of the proportion of the workforce on indirect activities, "I".

The project manager may also influence his level of backlog by improving the quality of proposals submitted to the DOD. This will improve his chances of having the proposal accepted and being awarded a contract. The quality of a proposal, and its associated capture rate is influenced by the quality of personnel used in preparing the proposal. Exhibit 6.3 shows this relationship where "%" and "I" signify the capture rate and quality of the indirect workforce, respectively.

Finally, the dollar volume of contracts awarded is a multiplicative function of the volume of new proposals and their associated capture rates. Exhibit 6.4 plots the volume of awarded contracts, "C". A general upward trend in the volume of awarded contracts is expected as the initial major project is scheduled to expire period 42. This will be discussed in more detail below.

A secondary, but related, concern of the project manager is the achievement of his volume or staff goal. Exhibit 6.5 plots the size of the labor force under the control of the project manager. As demonstrated, there are several periods where the labor force has decreased in size suggesting that firing and/or attrition has occurred. As mentioned previously, the project manager will fire only low quality personnel.

Exnibic 6.3

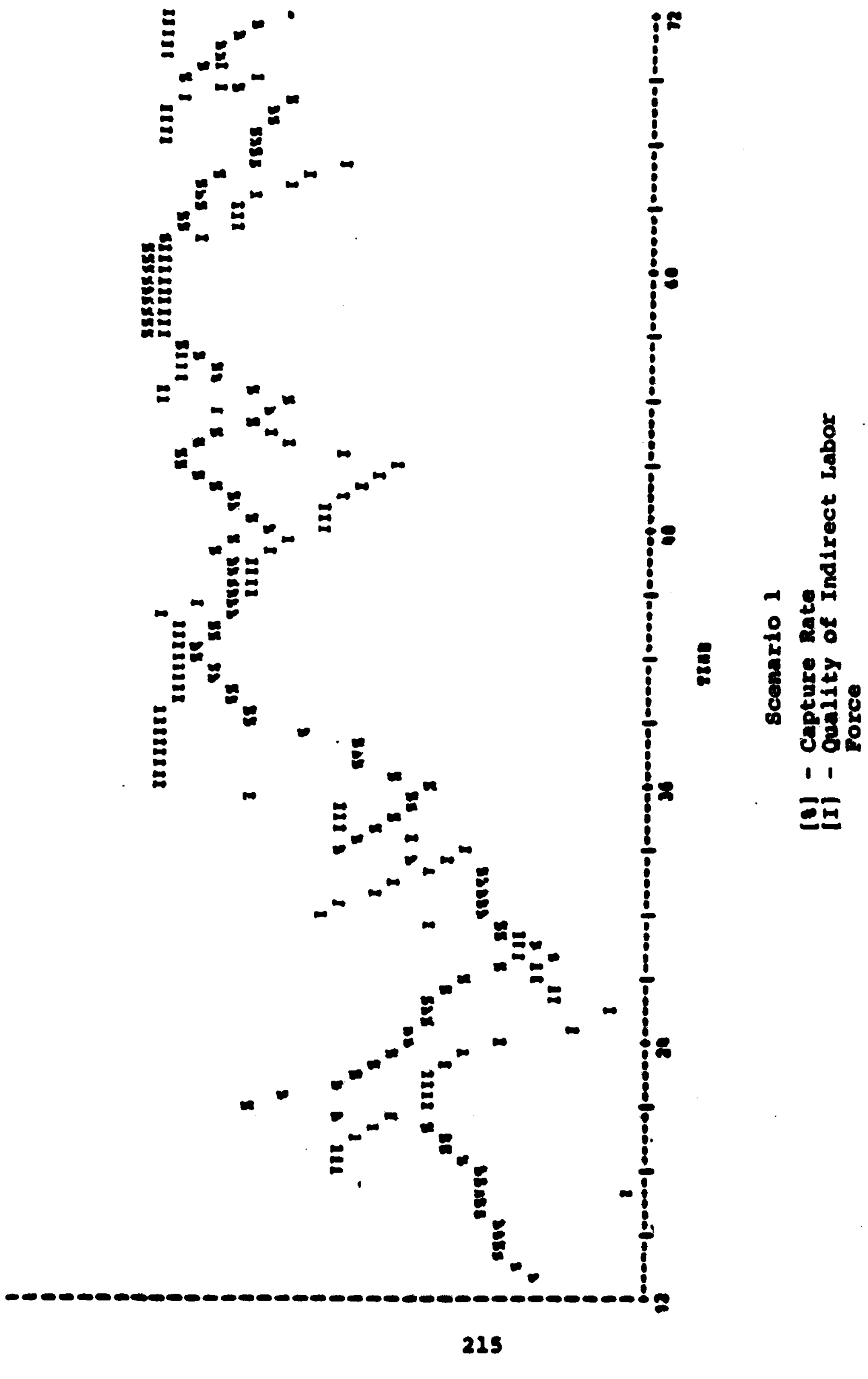

TIME
Scenario 1
[$] - Capture Rate
[I] - Quality of Indirect Labor Force

Exhibit 6.4

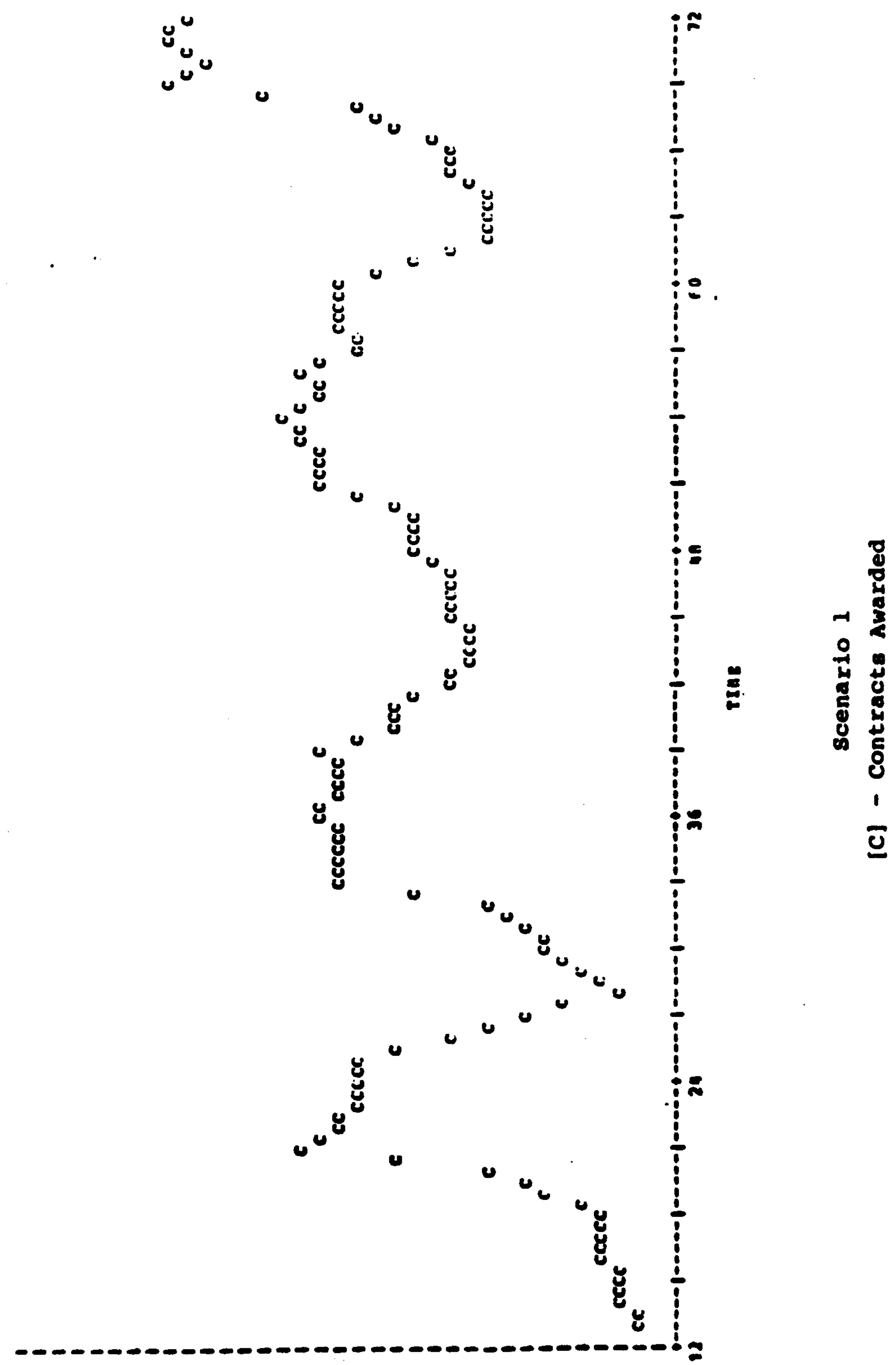
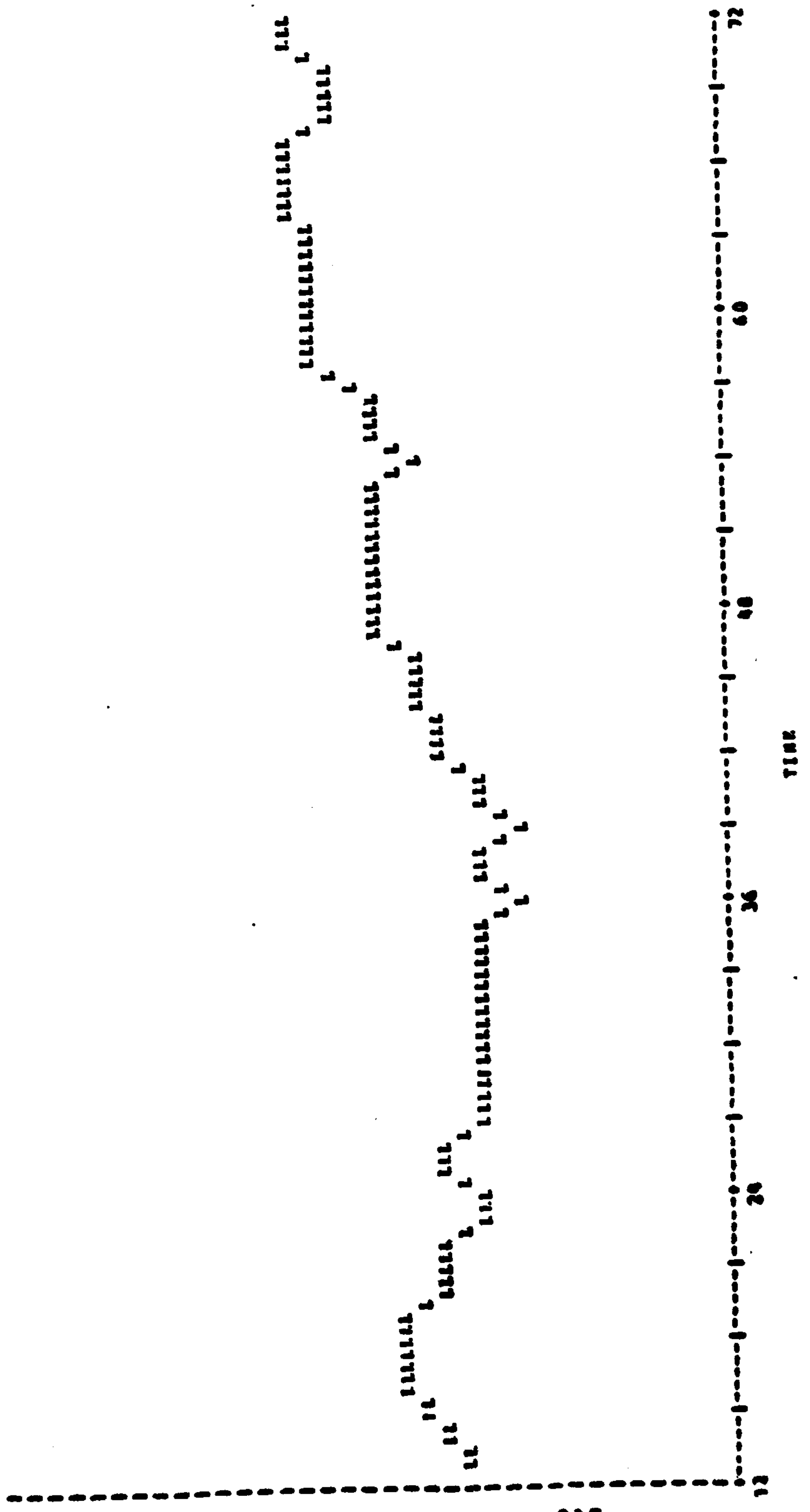


Exhibit 6.5



Scenario 1

[L] - Size of Labor Force

However, high quality personnel will voluntarily quite during prolonged periods of firing. This occurrence, combined with specified limits to the availability of high quality personnel, prevents the labor force quality index from increasing monotonically. The quality index, represented by "X", is plotted in Exhibit 6.6.

6.2.2 Corporate Considerations

The corporate level is concerned primarily with the cash flow performance of the project manager. When this is unsatisfactory pressure will be applied on the project manager to improve his cash position. Exhibit 6.7 shows the monthly cash flow performance of the project manager, "$", and the months where pressure, "P", was applied.

The mechanism by which the project manager reacts to corporate cash flow pressure is unchanged from the Stage I DPM. In order to improve the cash flow performance of his organization, the project manager must increase the amount of billable time charged against existing contracts. Therefore, we expect the proportion of the labor force working on direct activities to increase during periods of cash flow pressure. This is demonstrated in Exhibit 6.8 where the symbol "D" represents the proportion of the total workforce on direct. Note that the proportion tends to increase during periods of corporate pressure. Of course, this will necessarily result in less staff on indirect activities--specifically proposal writing.

Exhibit 6.6

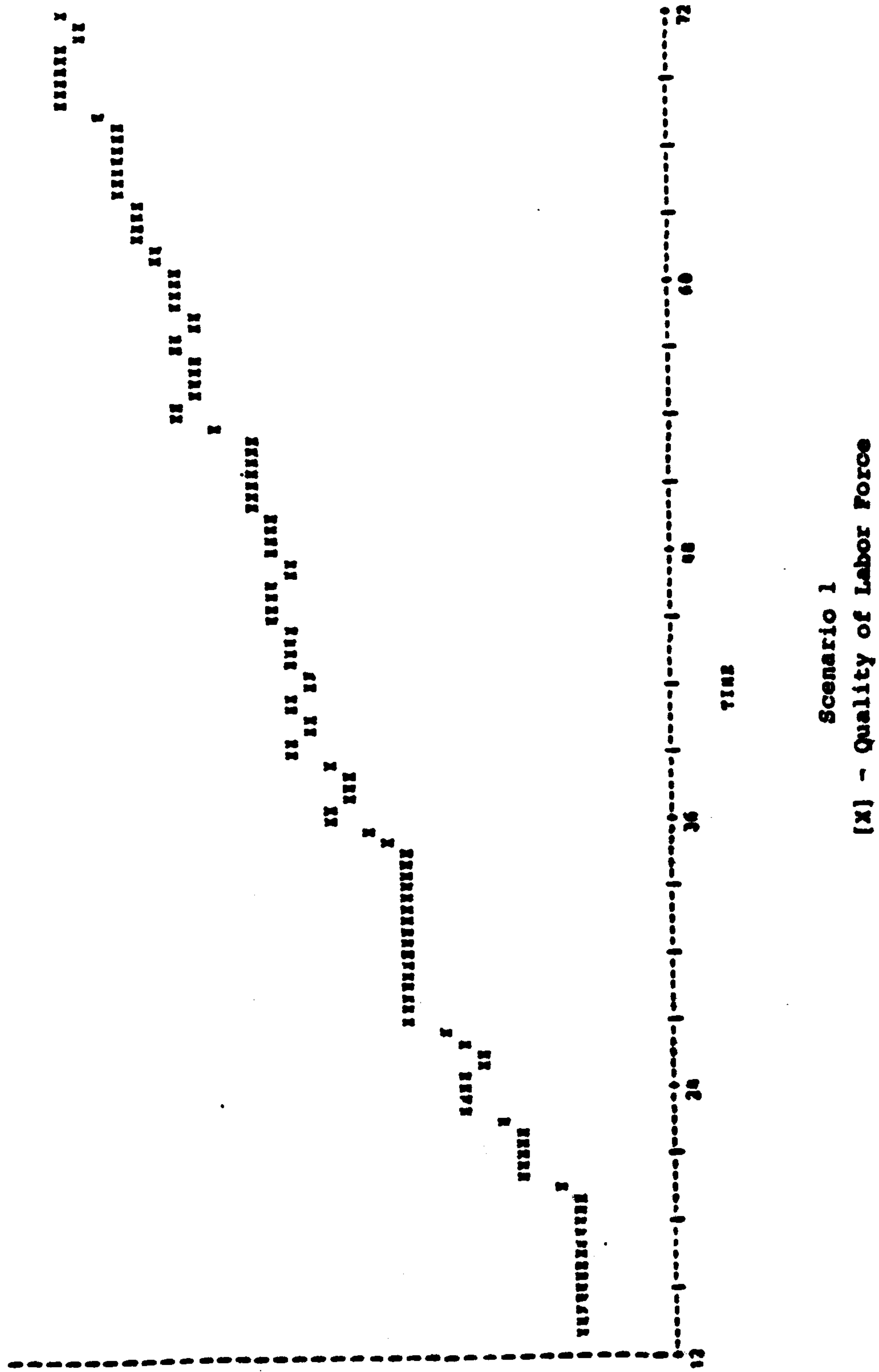


Exhibit 6.7

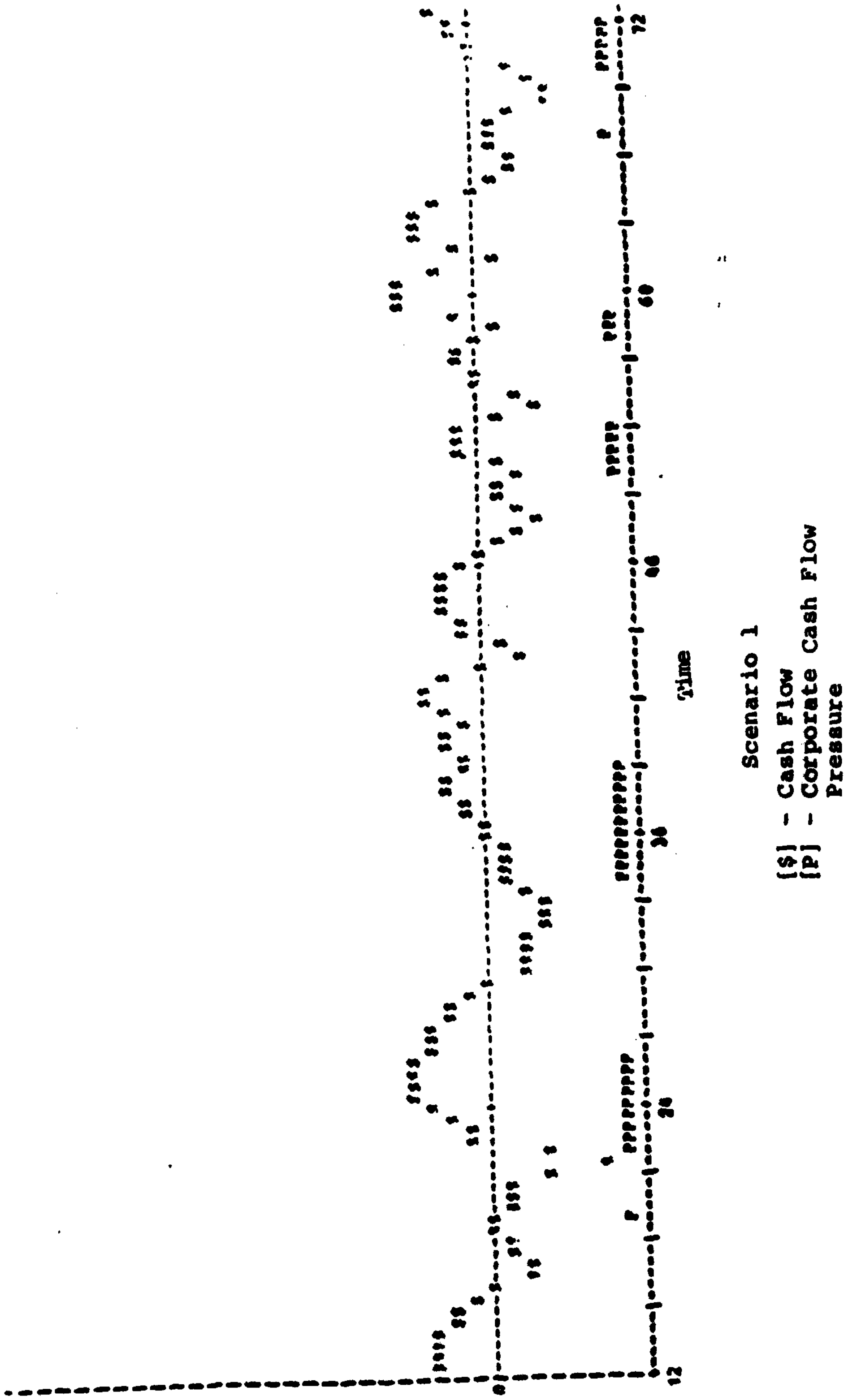
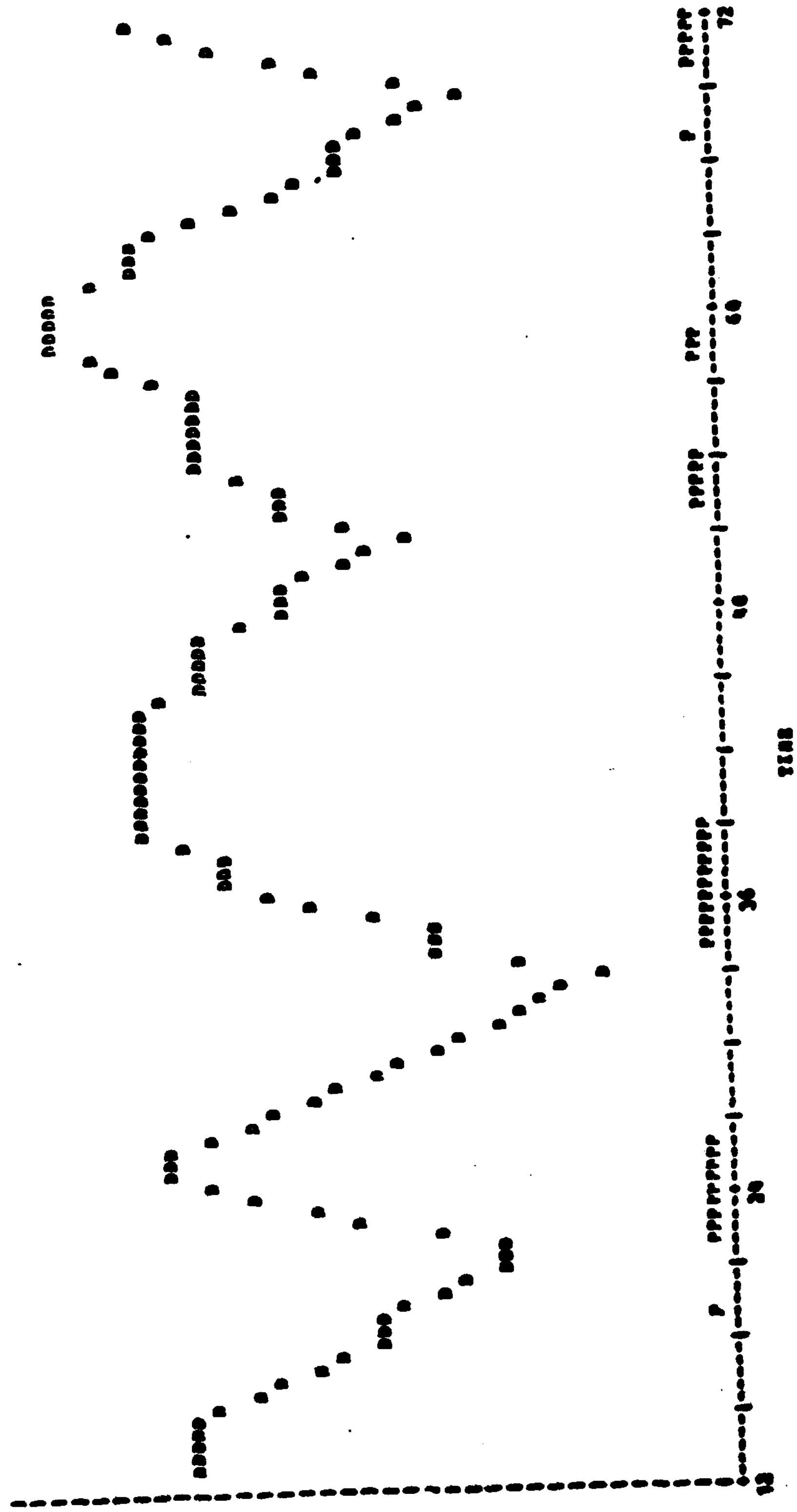

12
24
36
48
60
72
Time
Scenario 1
[$] - Cash Flow
[P] - Corporate Cash Flow
Pressure

Exhibit 6.8



Scenario 1
[D] - Proportion of Labor Force
Working Direct
[P] - Corporate Cash Flow
Pressure

As discussed previously, corporate allocations in support of IR&D and administrative expenses will increase in periods of favorable cash flow performance. This is demonstrated by Exhibit 6.9 where "T" represents the cumulative cash flow performance and "A" the level of corporate allocations. Note when the cumulative performance is increasing (i.e., periods of positive cash flow) that allocations are also increasing.

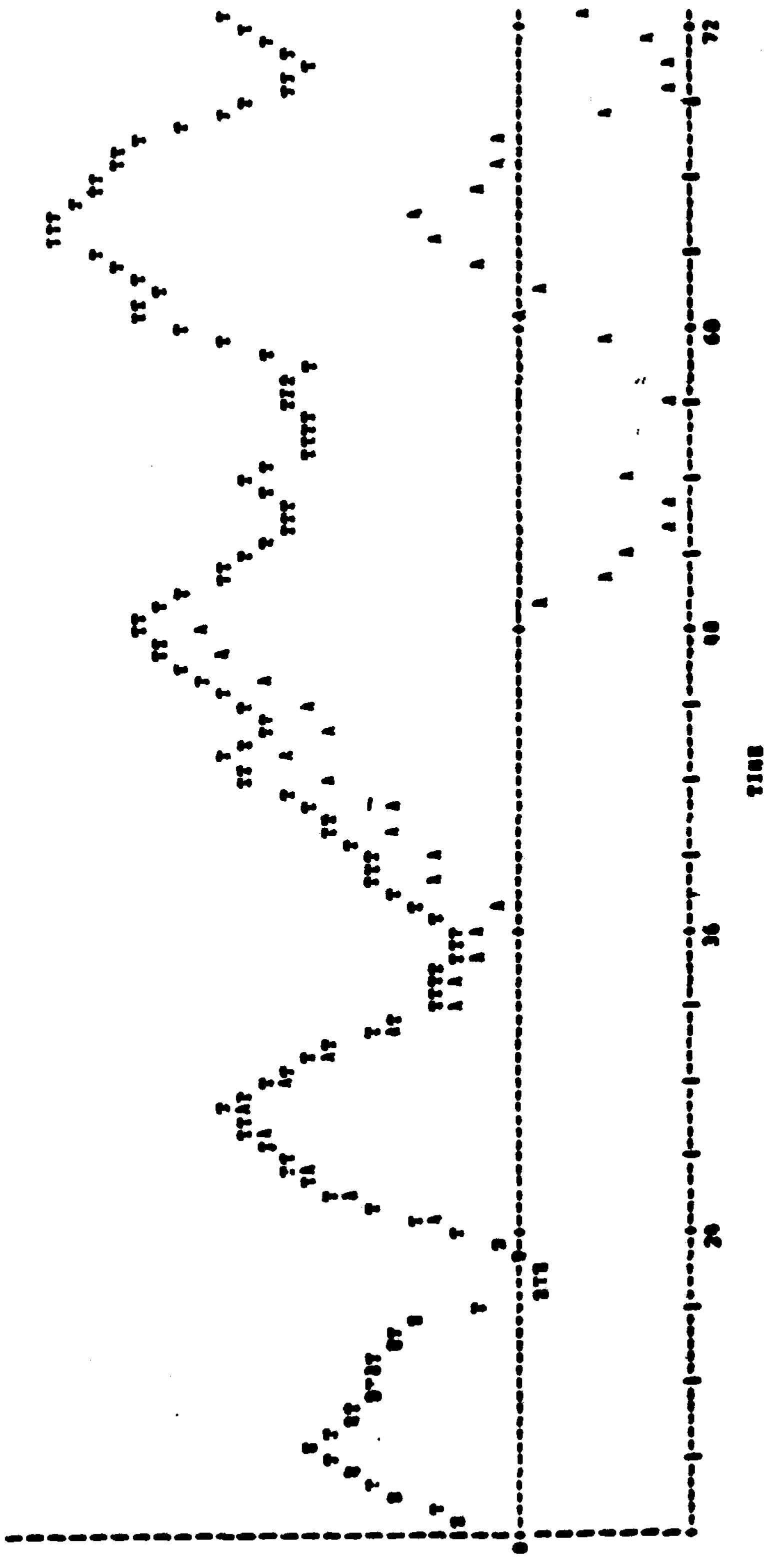
6.2.3 DOD Considerations

The DOD is assumed to monitor the performance of the project manager on individual projects. Specifically, the DOD is concerned with costs, schedule and quality of the Major Project. As discussed earlier in this report, the exhaustion of the SQMM balance does not necessarily coincide with that of the dollar budget. As demonstrated in Exhibit 6.10, the dollars remaining in the budget, "R", expire in period 37 while the SQMM requirement, "M", is not completed until period 41. This has the expected stifling effect on the project manager's cash flow performance.

The DOD is assumed to also be interested in completion of the project by the agreed-upon delivery date. Because the project was completed in period 41 and not due until 42, no DOD Schedule Pressure was applied.

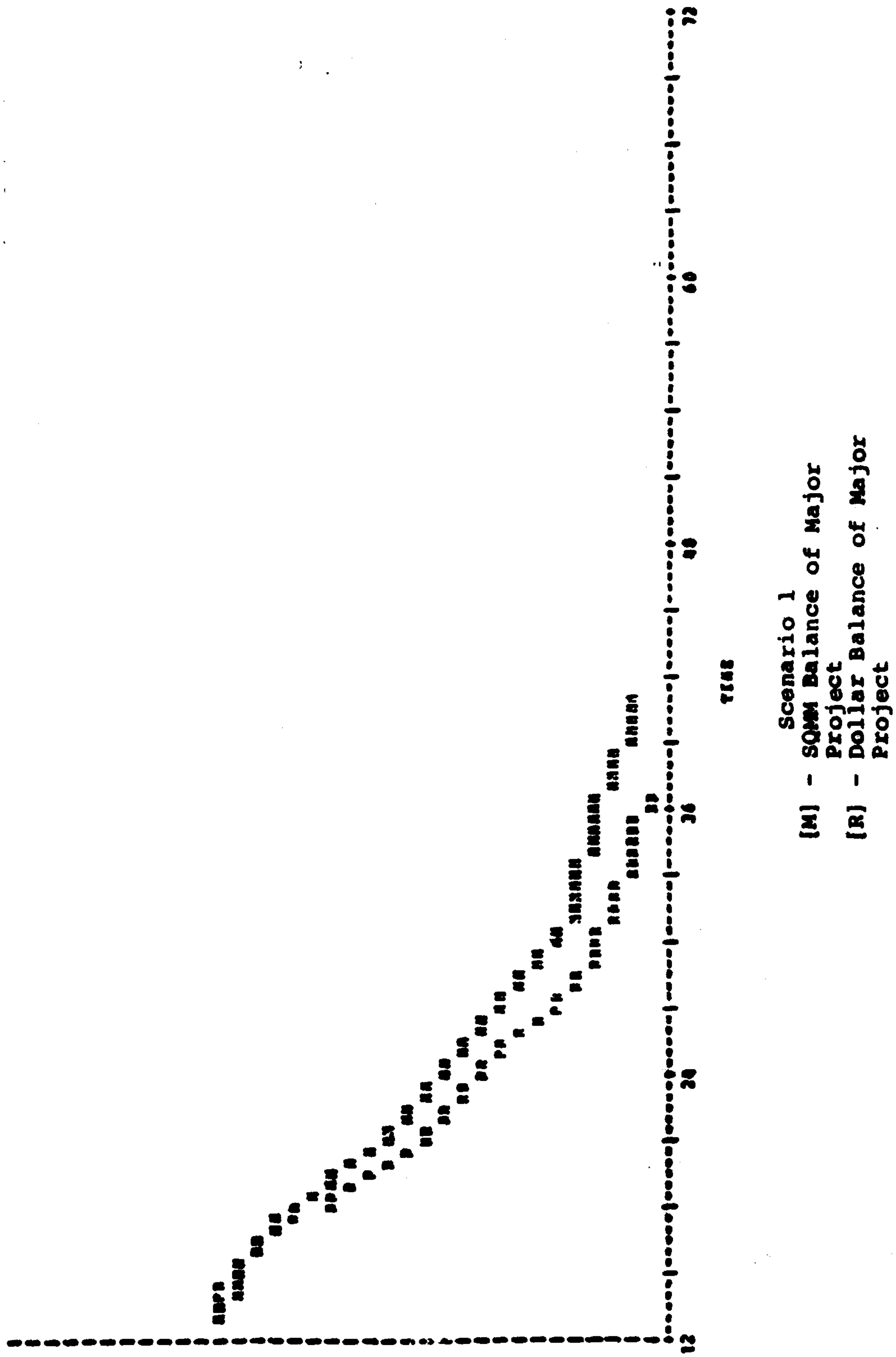
The primary concern of the DOD is the quality performance of the Major Project. When the quality of work on the Major

Exhibit 6.9



Scenario 1
[T] - Cumulative Cash Flow
[A] - Corporate Allocations

Exhibit 6.10


TIME
Scenario 1
[M] - SQMM Balance of Major Project
[R] - Dollar Balance of Major Project

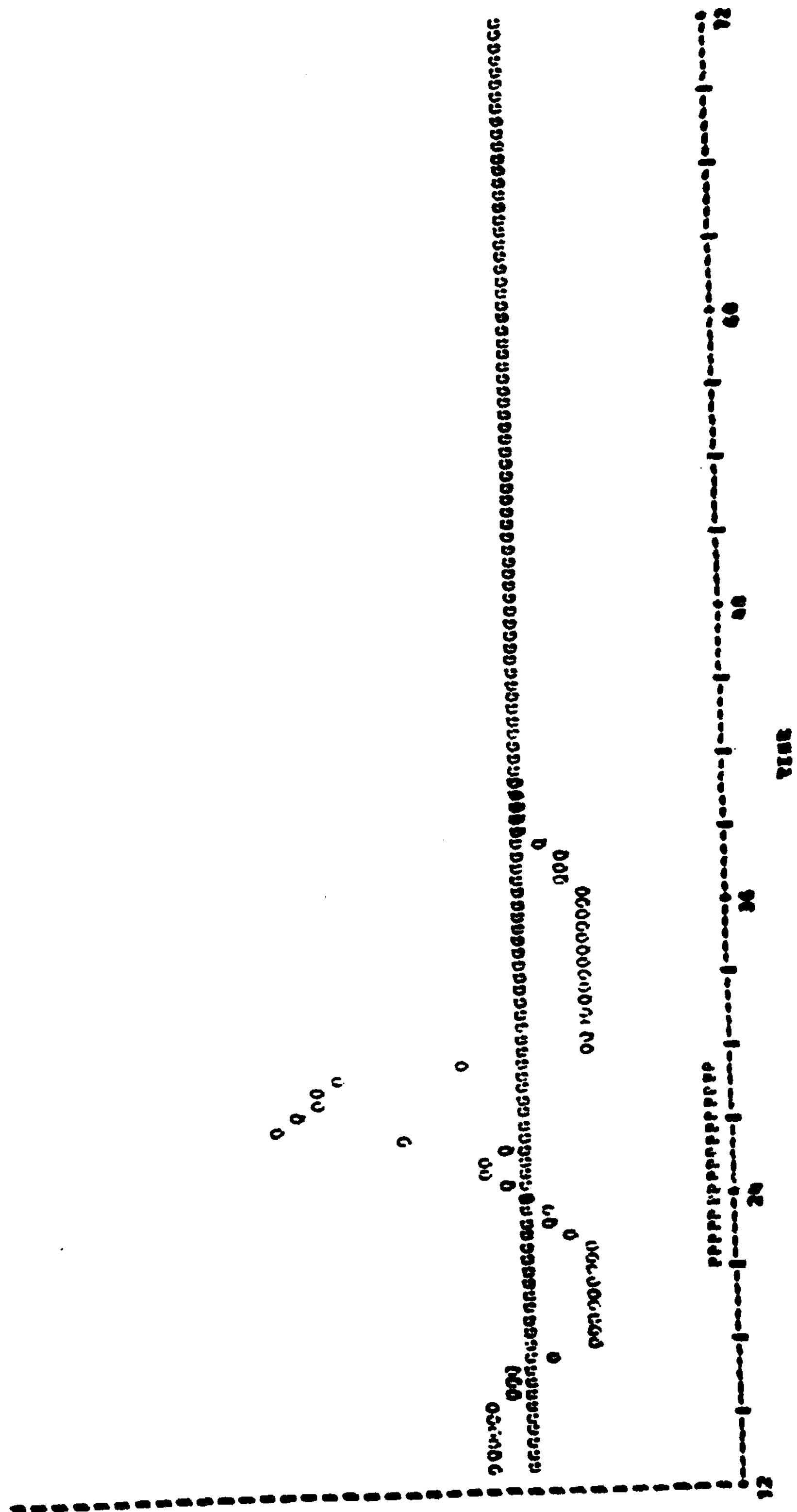
Project is unsatisfactory, the DOD may apply pressure. Exhibit 6.11 plots the current quality of performance, "Q", the quality goal, "G", and the occurrence of project manager quality pressure, "P". Note that project manager pressure is applied when the current quality performance is consistently below the goal.

The DOD will apply quality pressure at the corporate level when pressure on the project manager has not been effective. Exhibit 6.12 shows the cumulative quality performance, "T", and corporate level quality pressure, "C". The application of corporate quality pressure by the DOD is shown to have a more immediate impact than project manager quality pressure as discussed earlier.

6 .3 Scenario 2: No DOD Monitor

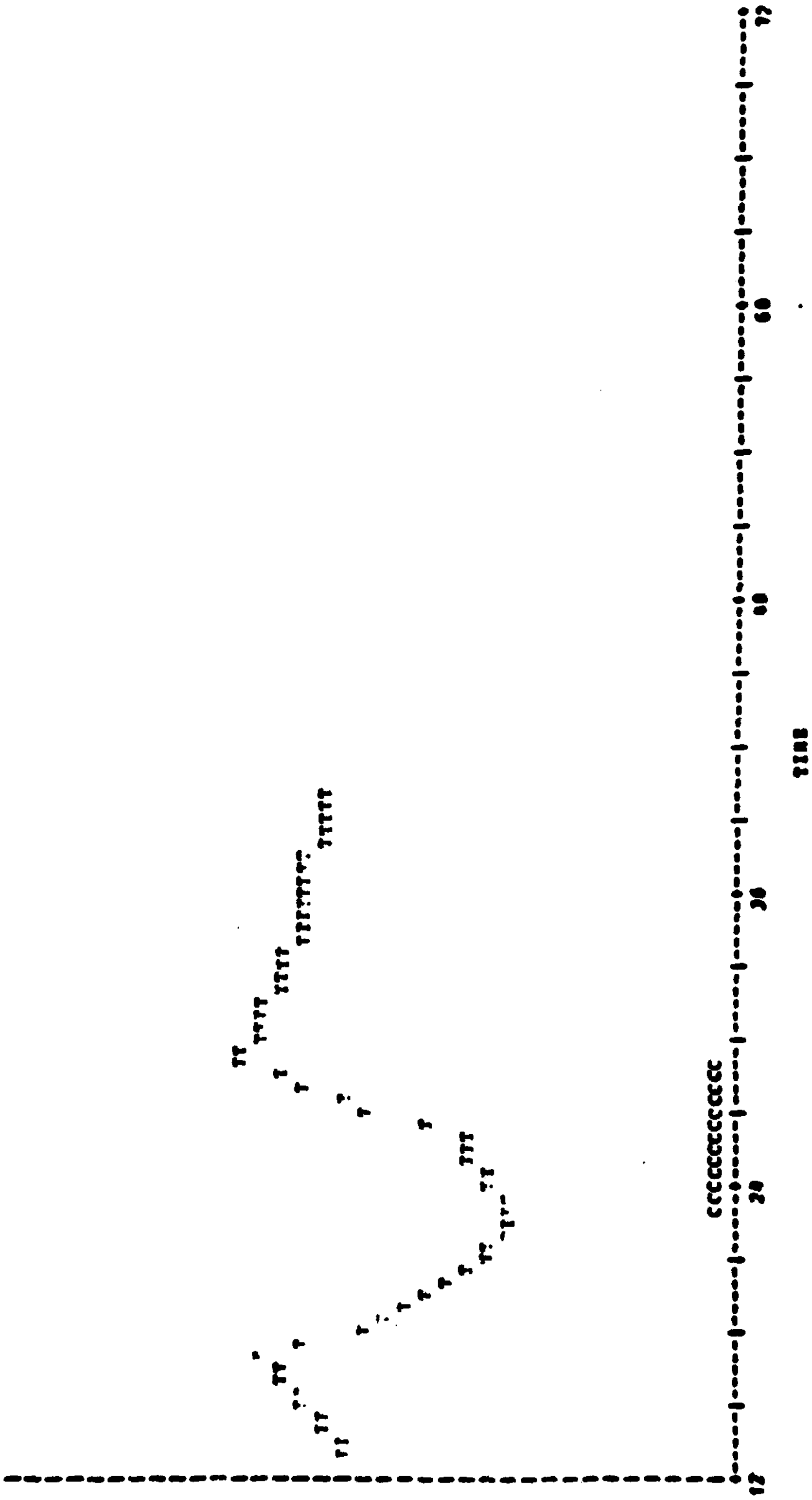
The purpose of generating this scenario is to investigate the effect the DOD monitor (and the associated quality and schedule pressure mechanism) has on the behavior of the project manager and the overall system performance. It is assumed that the DOD will not apply schedule or quality pressure at the corporate or project manager level. It is further assumed, however, that the DOD will not accept the major project unless the minimum quality goal has been achieved. Additional high quality work is required to be performed if the quality of an otherwise completed project is less than the minimum acceptable standard. As in Scenario 1, only one Major Project is assigned to the project manager.

Exhibit 6.11



Scenario 1
[Q] - Current Quality Performance
[G] - Quality Goal
[P] - Project Manager Quality
Pressure

Exhibit 6.12



Scenario 1

[T] - Overall Quality of Performance

[C] - Corporate Quality Pressure

6.3.1 Project Manager Considerations

Exhibit 6.13 plots the actual months of backlog with the upper and lower acceptable boundaries. A brief comparison with Exhibit 6.1 suggests that the months of backlog are greater than the standard scenario--especially in the final periods of the simulation. Note that the backlog goals are dynamic and have been adjusted upward to levels different than those in Scenario 1.

Apparently, the project manager has been awarded a larger number of contracts and/or is employing a smaller labor force than in the earlier scenario. Examination of Exhibit 6.14, which plots the size of the labor force under the responsibility of the project manager, shows the size of the workforce to be significantly larger than Scenario 1 (see Exhibit 6.5). This suggests the project manager has been awarded many more contracts in Scenario 2.

Exhibit 6.15 plots the volume of new proposals submitted to the DOD and the proportion of the workforce assigned to indirect activities. Comparison with Exhibit 6.3 provides no explanation of why a larger number of contracts were awarded. However, Exhibit 6.16, which shows the capture rate and quality of the indirect workforce, reveals a significant difference between the two scenarios (see Exhibit 6.3). The quality of the indirect workforce and the associated capture rate is much greater, on the average, in Scenario 2.

Exhibit 6.13

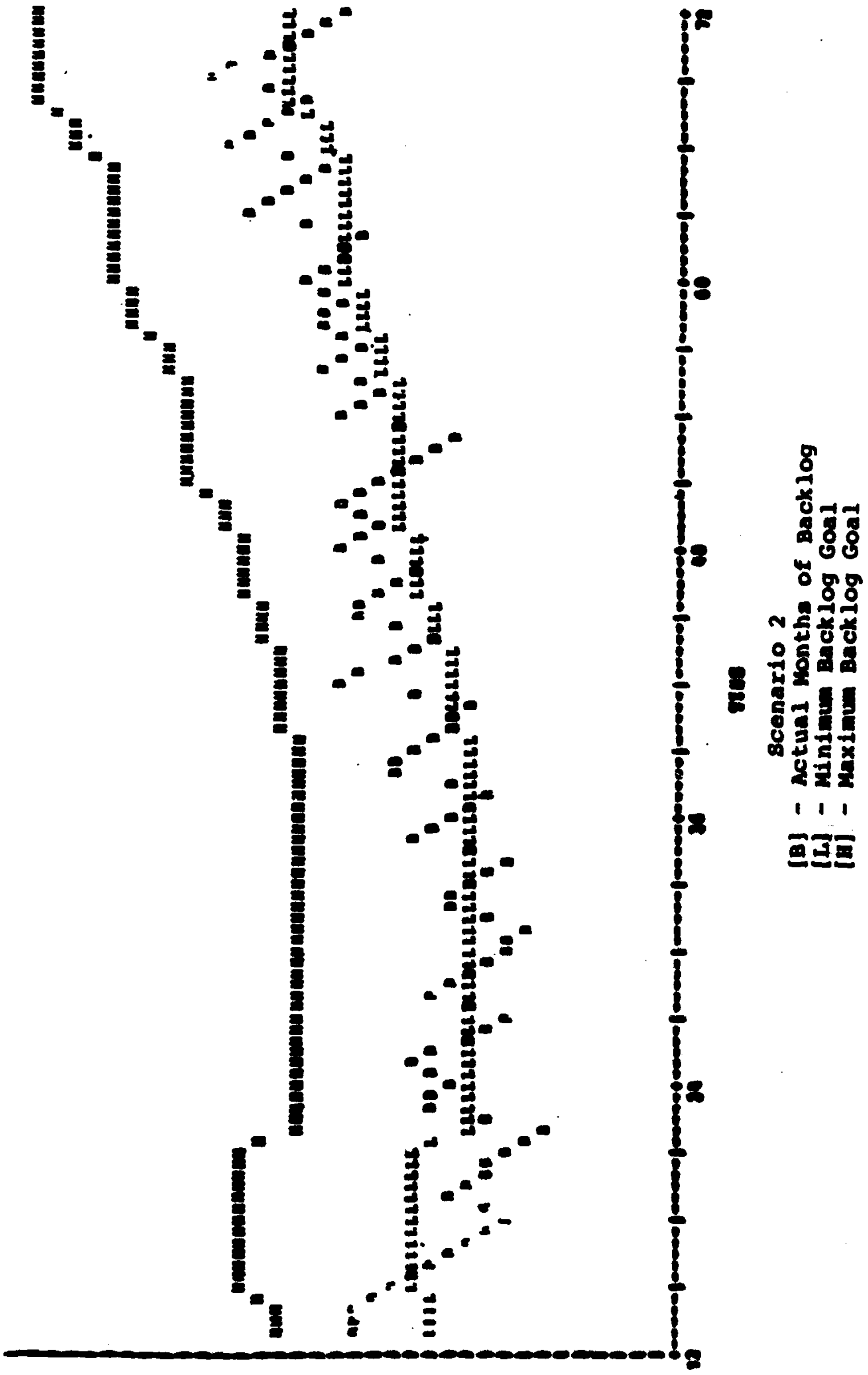
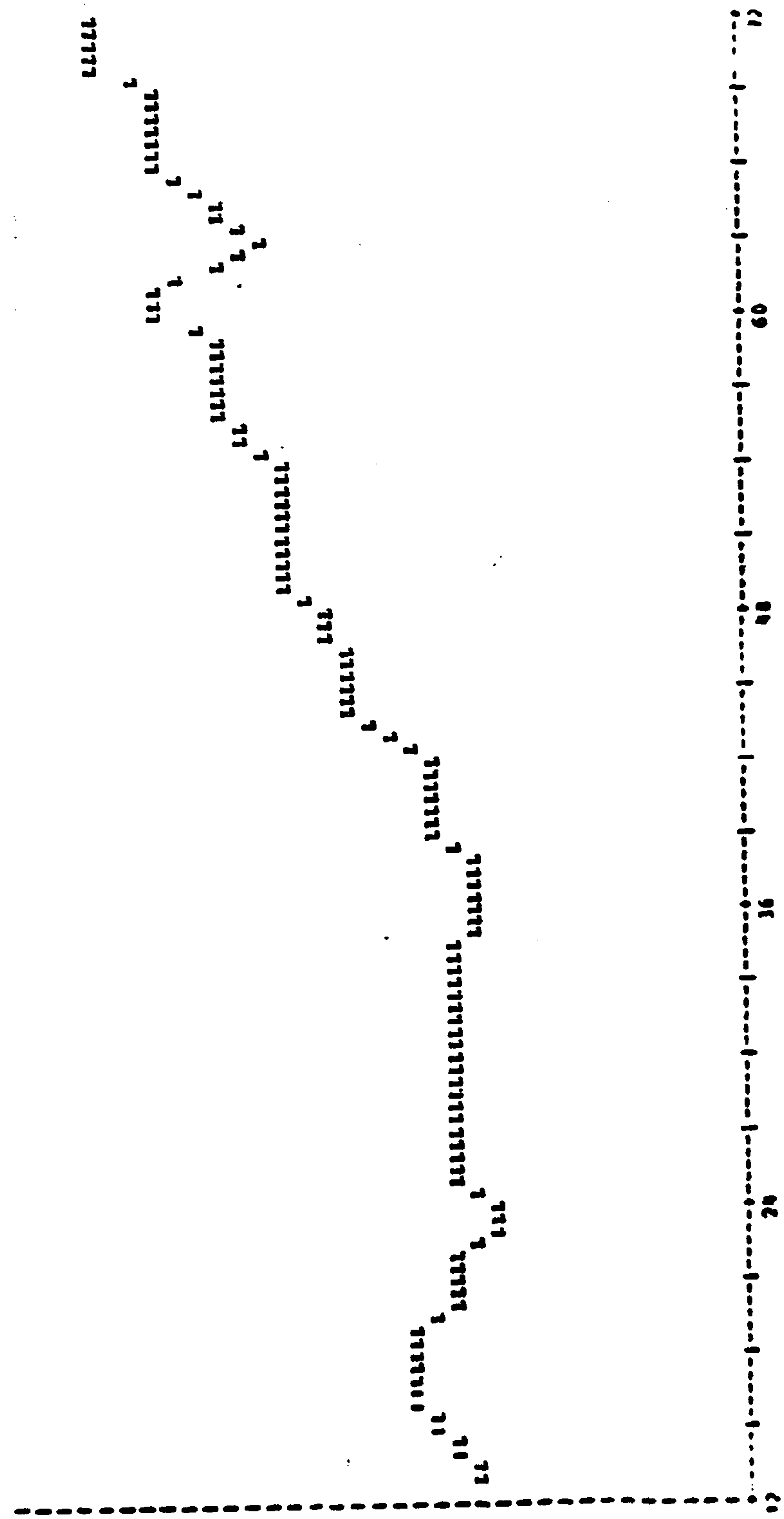

TIME
Scenario 2
[B] - Actual Months of Backlog
[L] - Minimum Backlog Goal
[H] - Maximum Backlog Goal

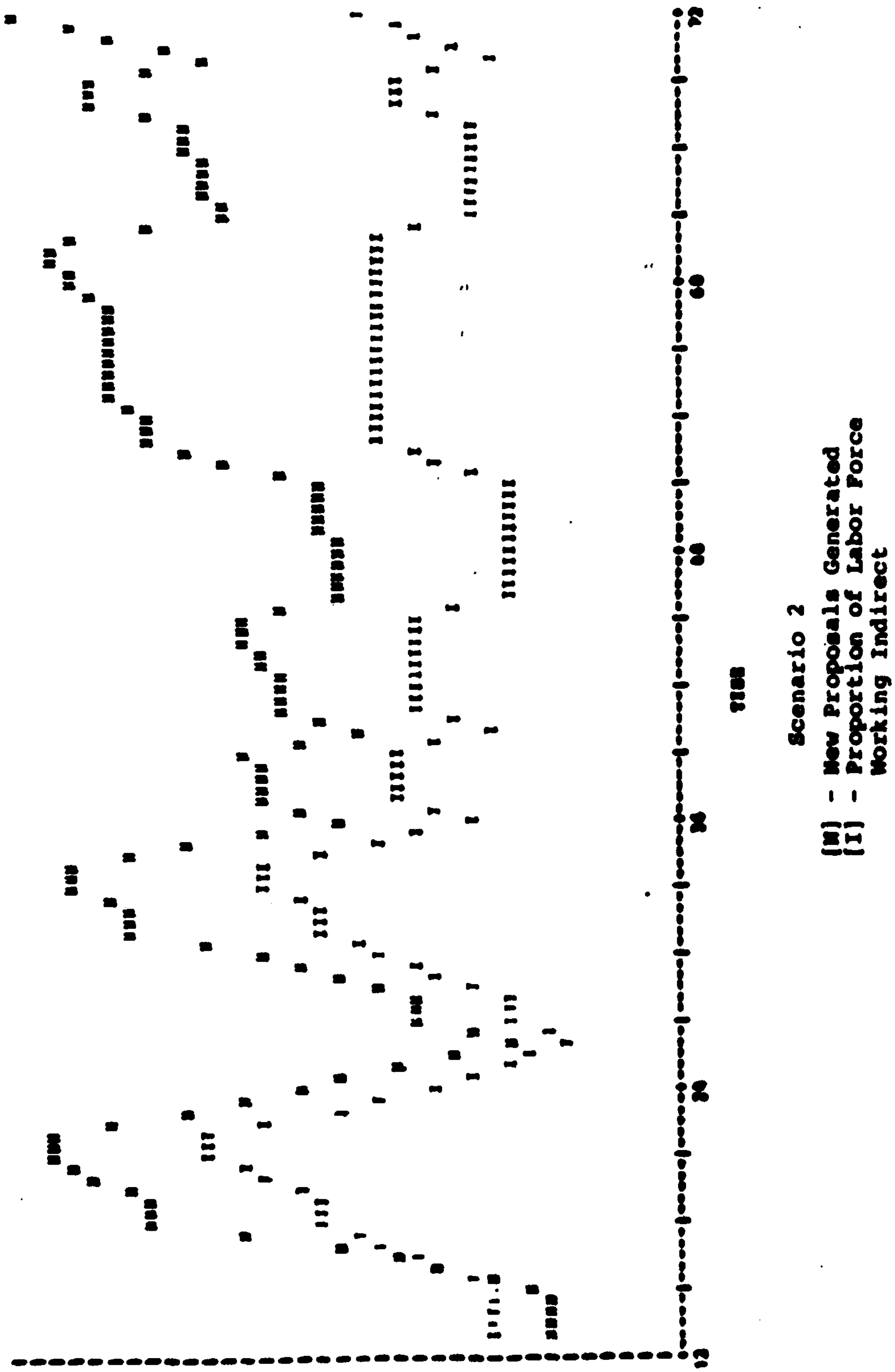
Exhibit 6.14



Scenario 2

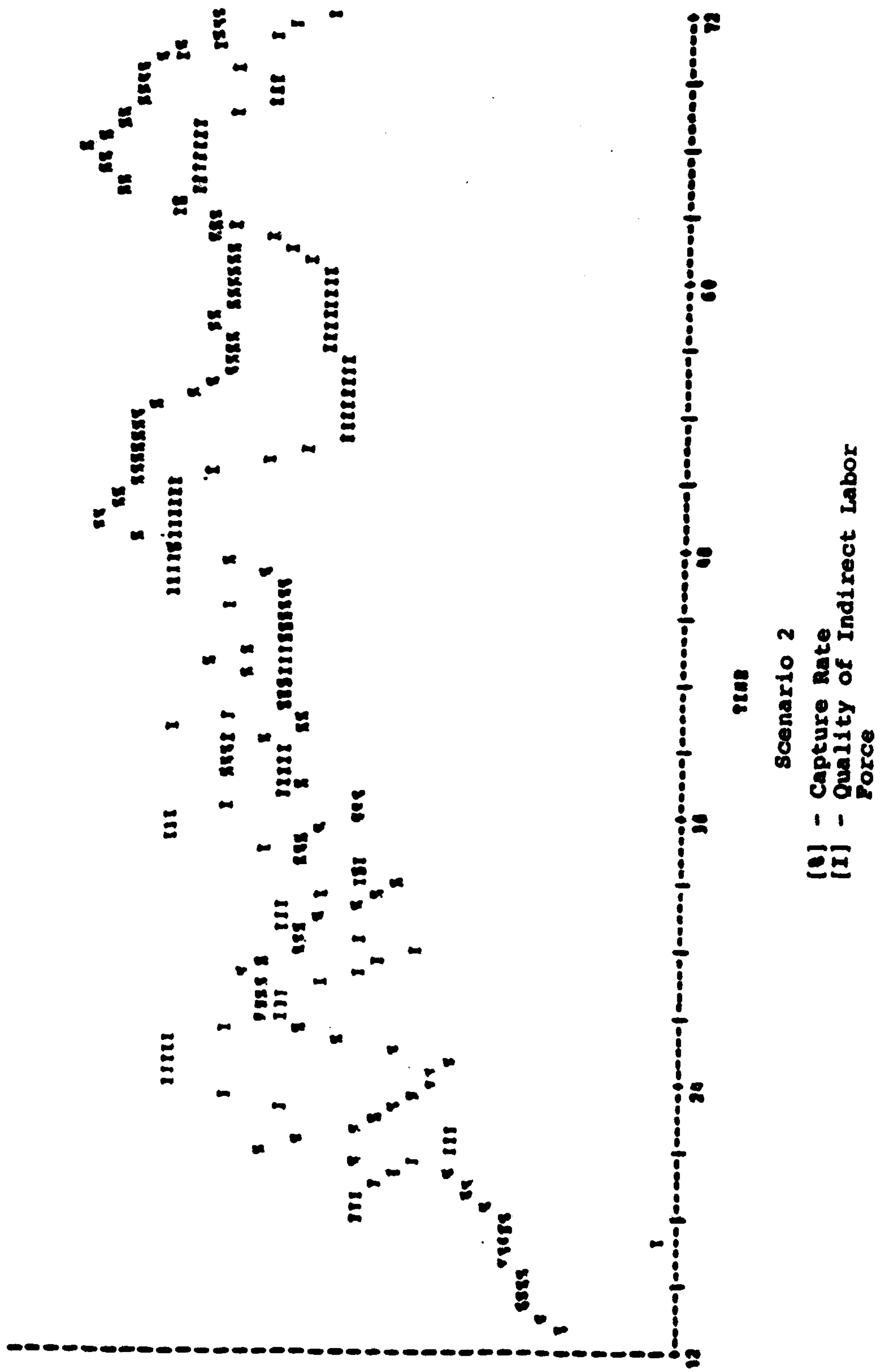
[L] - Size of Labor Force

Exhibit 6.15



12
24
36
48
60
72
TIME
Scenario 2
[N] - New Proposals Generated
[I] - Proportion of Labor Force
Working Indirect

Exhibit 6.16



Because the project manager was not required, via DOD quality pressure, to sustain a relatively constant level of quality on the Major Project, higher quality personnel were used to write proposals than in the standard scenario. Higher quality proposals resulted in higher capture rates and, consequently, a larger number of awarded contracts.

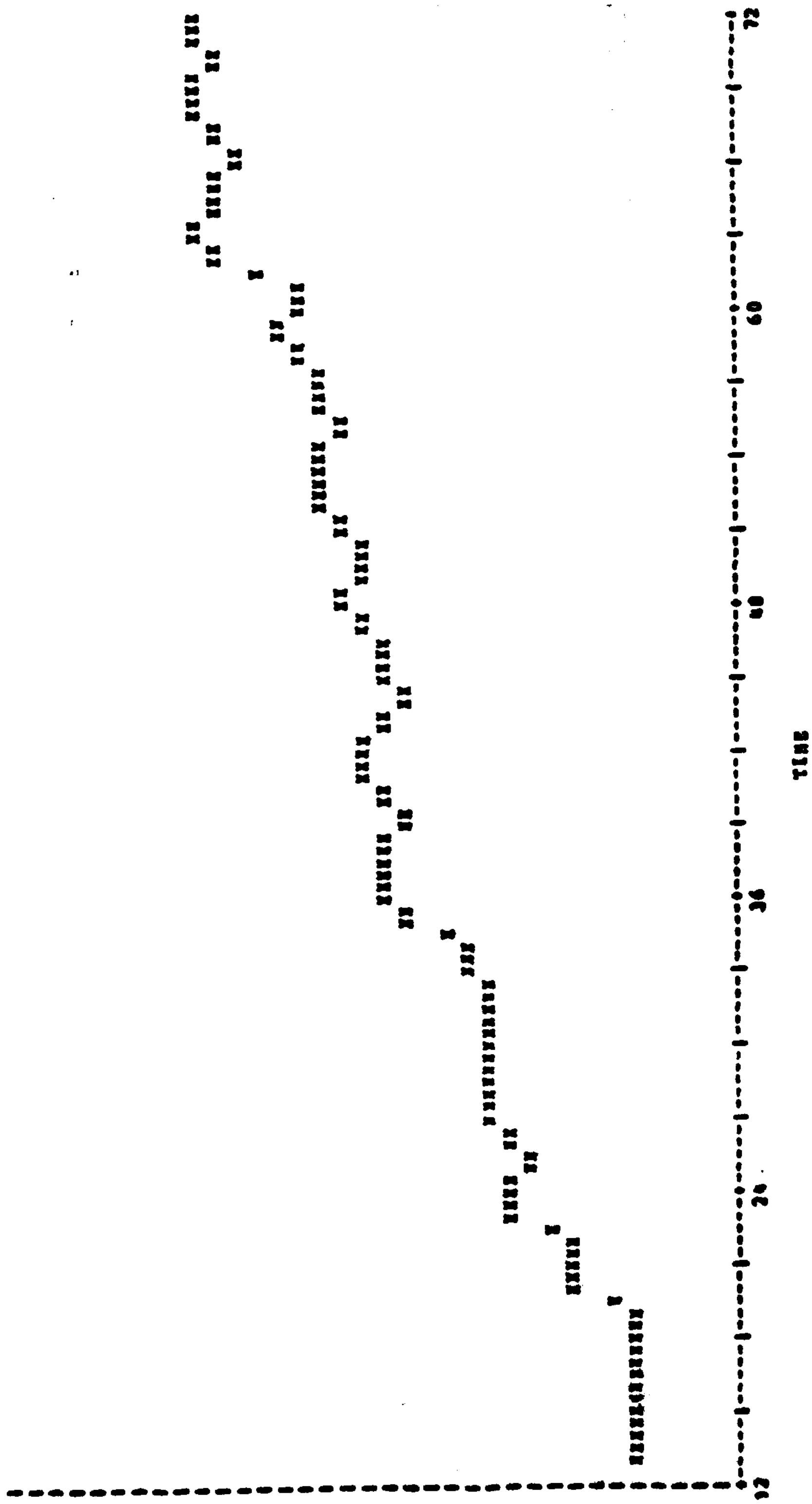
Unfortunately, this relatively higher level of prosperity is not without its problems. Besides the quality and schedule considerations of the DOD (discussed below), the project manager must now contend with a lower quality labor force. As demonstrated by comparing Exhibit 6.17 with Exhibit 6.6, the quality composition of the workforce has decreased. This is a direct result of limits to the availability of high quality workers when attempting to increase the size of the labor force.

6.3.2 Corporate Considerations

Exhibit 6.18 shows the cash flow performance in conjunction with the periods where pressure was applied on the project manager by corporate. While comparison with Exhibit 6.7 reveals little difference in the cash flows, there were fewer periods of cash flow pressure in Scenario 2. In addition, Exhibit 6.19, when compared with Exhibit 6.9, shows a more favorable cumulative cash flow performance.

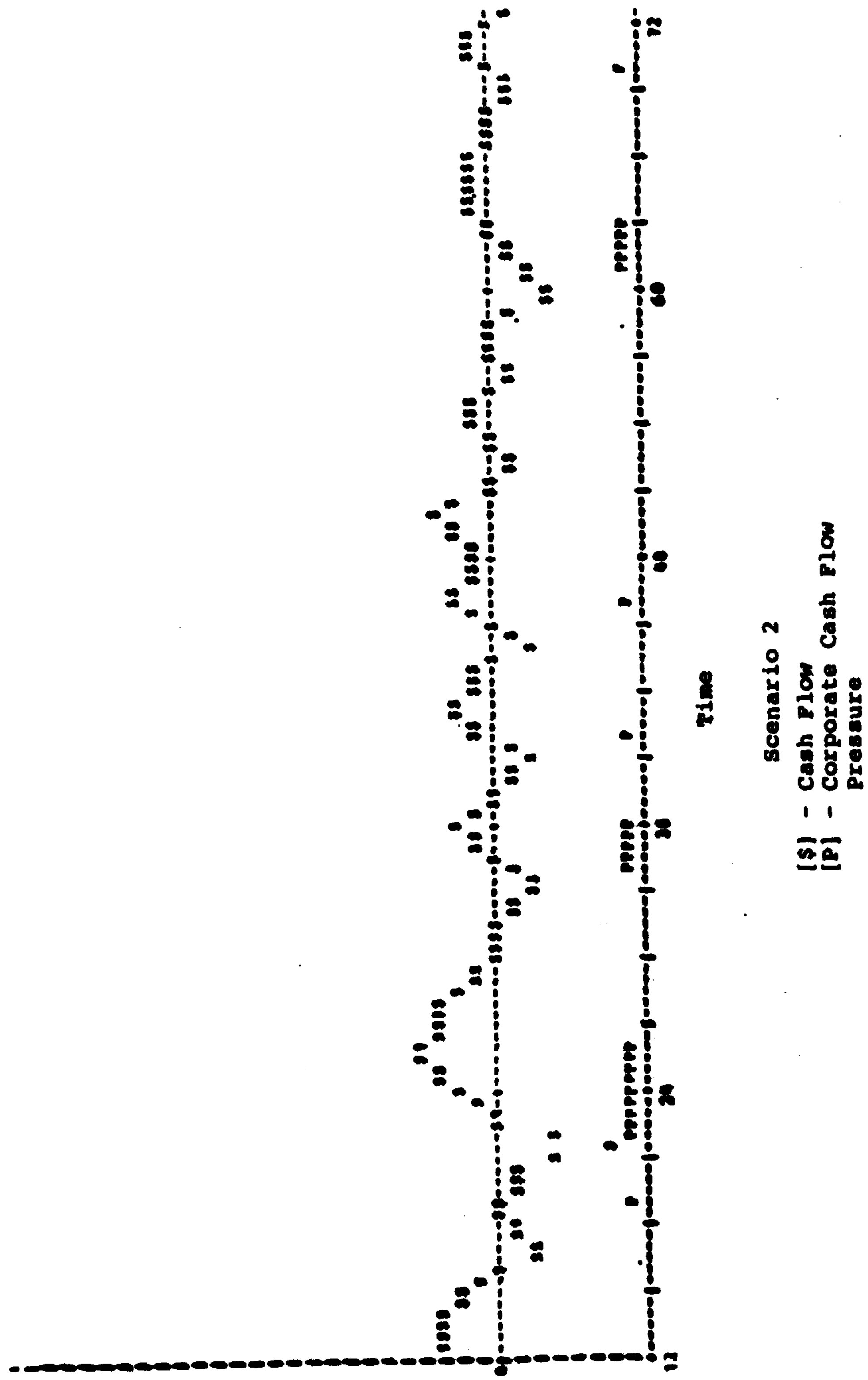
The absence of DOD pressure seems to have slightly influenced the cash flow performance of the project manager in a positive

Exhibit 6.17



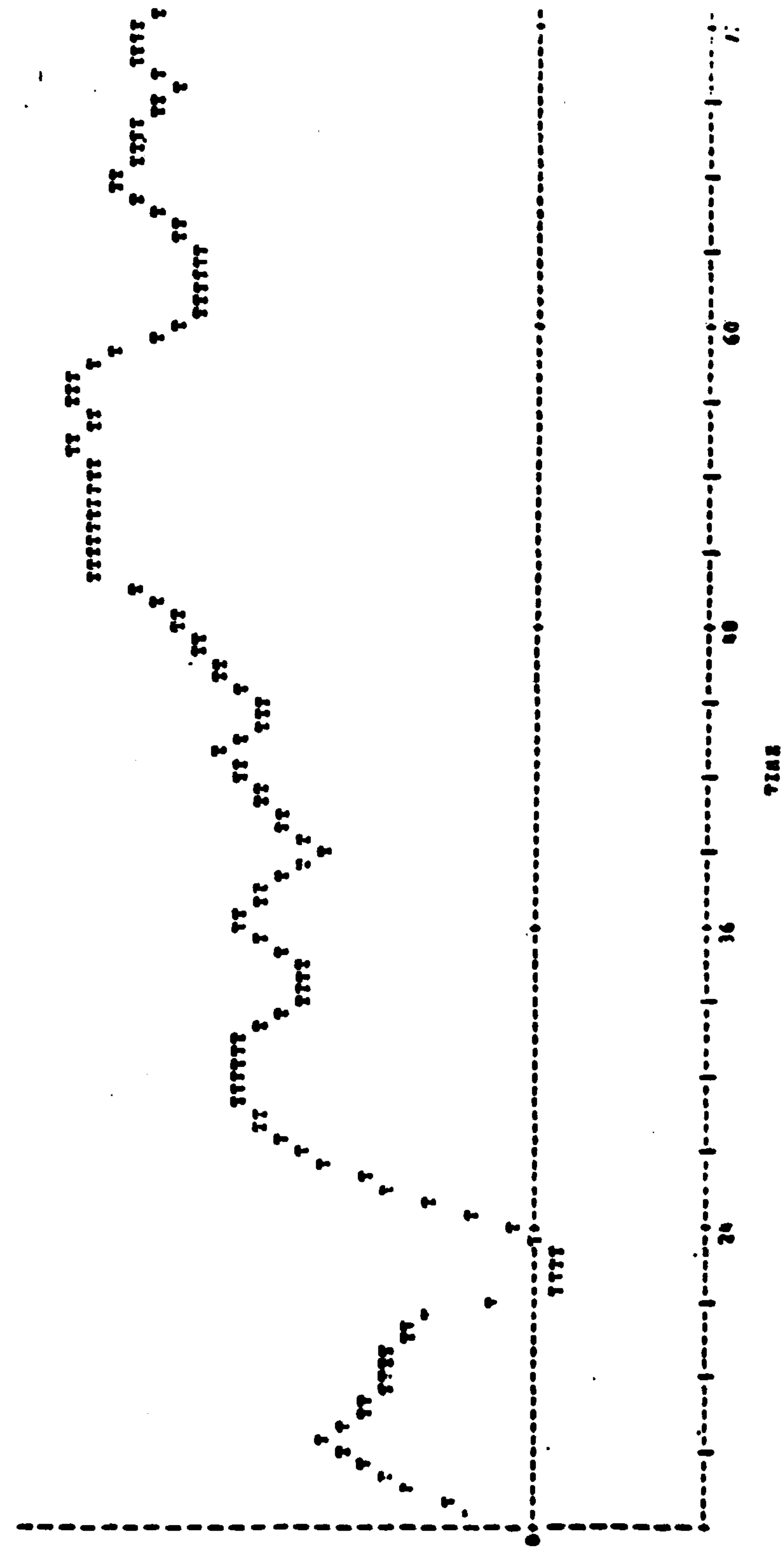
Scenario 2
[X] - Quality of Labor Force

Exhibit 6.18



12
24
36
48
60
72
Time
Scenario 2
[$] - Cash Flow
[P] - Corporate Cash Flow
Pressure

Exhibit 6.19



Scenario 2

[T] - Cumulative Cash Flow

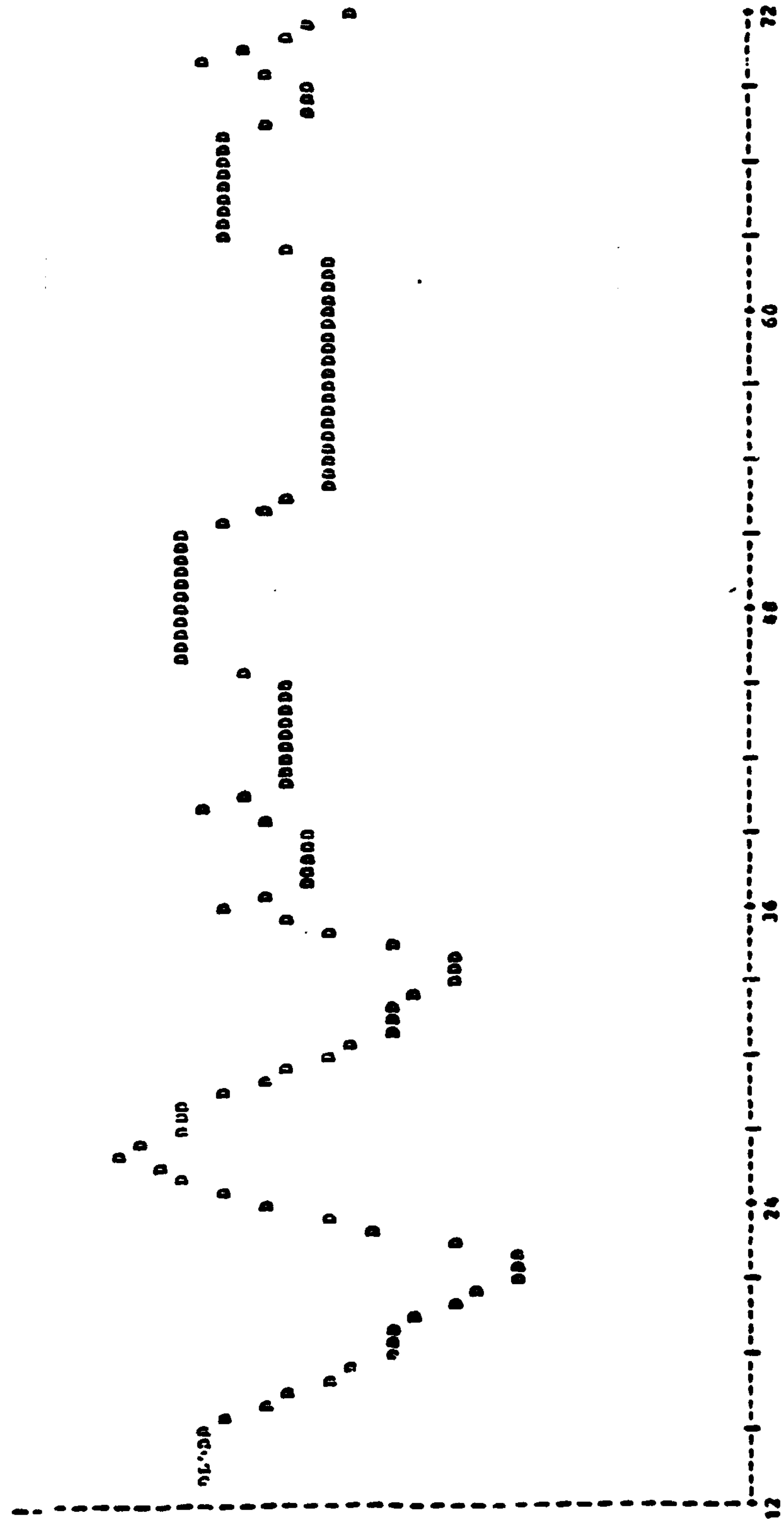
direction. The major reason for this is the project manager's ability to maintain an acceptable level of backlog with a high capture rate instead of large transfers of workers to indirect (proposal writing) activities. The relatively constant level of workers on direct, as shown in Exhibit 6.20 (vis-a-vis Exhibit 6.8), enabled the project manager to avoid large negative fluctuation in his cash position.

6.3.3 DOD Considerations

As demonstrated in Exhibit 6.21, Scenario 2 presented much more serious budgeting and scheduling problems for the project manager than the standard scenario (see Exhibit 6.10). While the Major Project was due in period 42, it was not completed until period 48. (As we shall see below, the reason for this was an unacceptable quality performance.) *In addition to* the scheduling problem, the project manager had completely exhausted the dollar budget of the Majro Project by period 39.

Exhibit 6.22 displays the current quality index and the minimum acceptable quality goal as enforced by the DOD. Because the DOD monitor was not included in this simulation, the project manager was not induced to maintain his current quality performance near or above the minimum level (see Exhibit 6.11). When the SQMM balance was completed in approximately period 42, the project manager was forced to provide additional high quality work in order to improve the cumulative quality performance to an acceptable level. This is demonstrated in

Exhibit 6.20



Scenario 2
[D] - Proportion of Labor Force
Working Direct

Exhibit 6.21

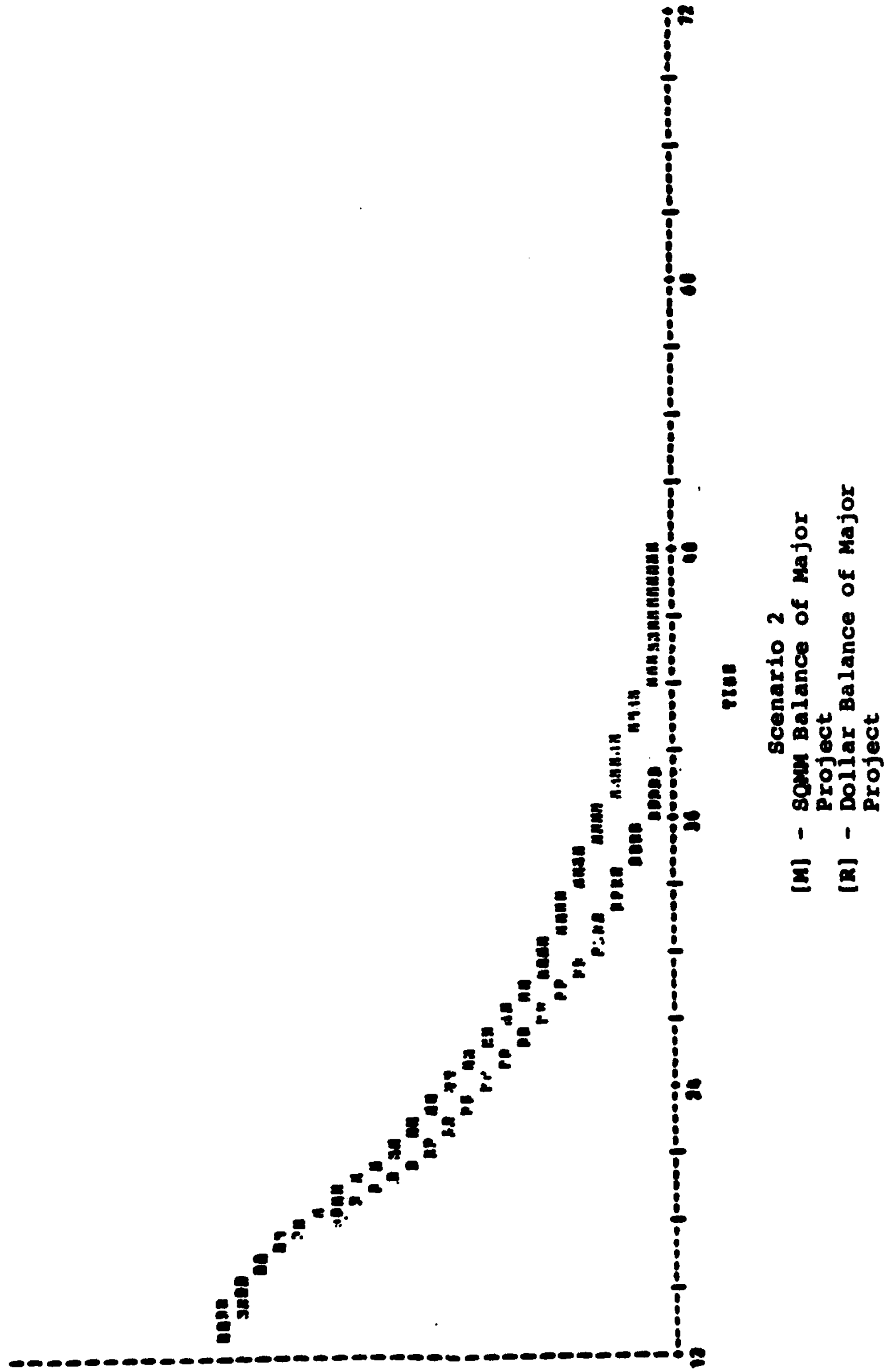

TIME
Scenario 2
[M] - SQMM Balance of Major Project
[R] - Dollar Balance of Major Project

Exhibit 6.22

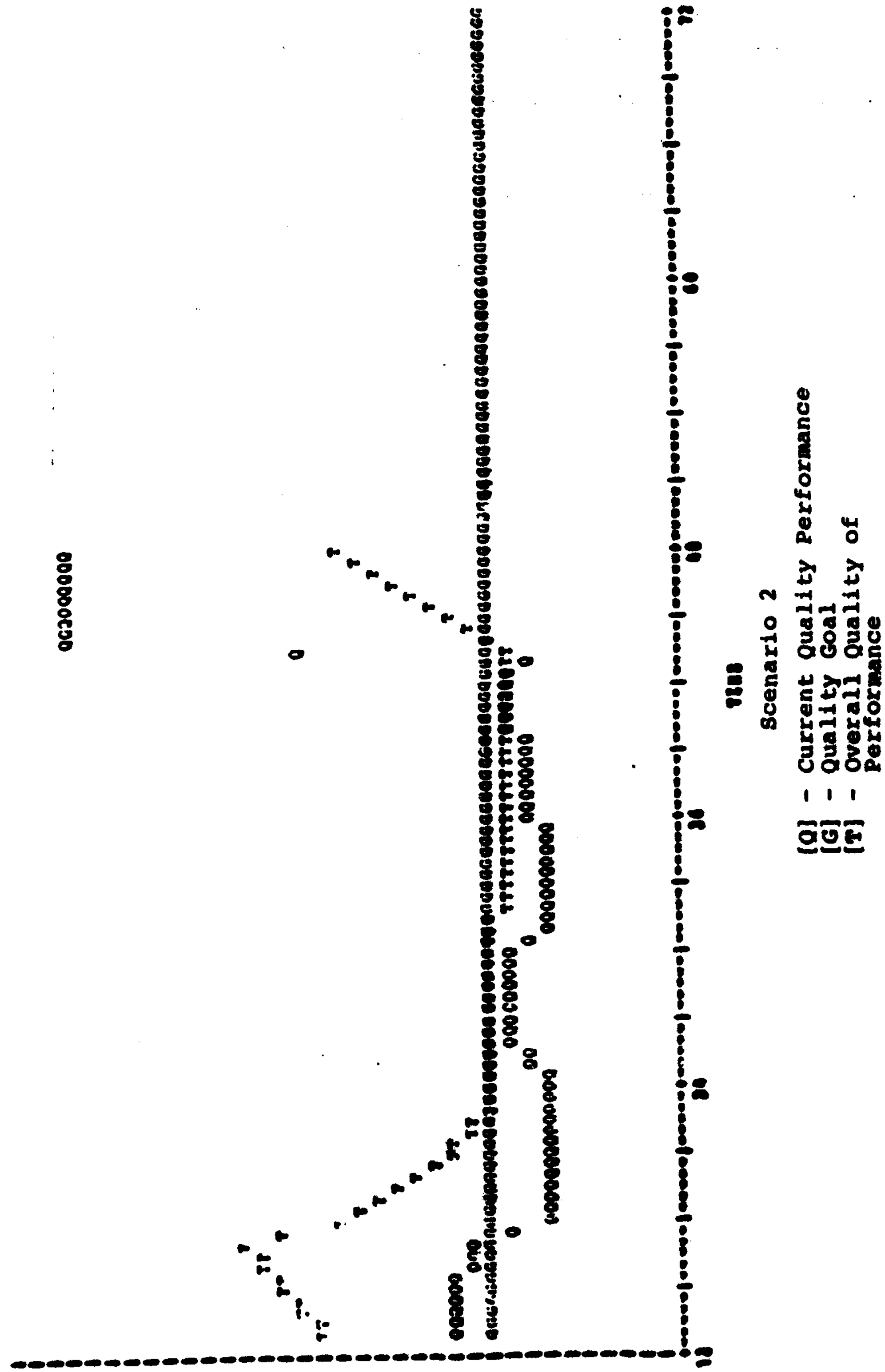

TIME
Scenario 2
[Q] - Current Quality Performance
[G] - Quality Goal
[T] - Overall Quality of Performance

Exhibit 6.23 which is comparable to Exhibit 6.12 in the standard scenario. An additional six months of high quality work, financed by the contractor, was necessary before the project was considered acceptable to the DOD.

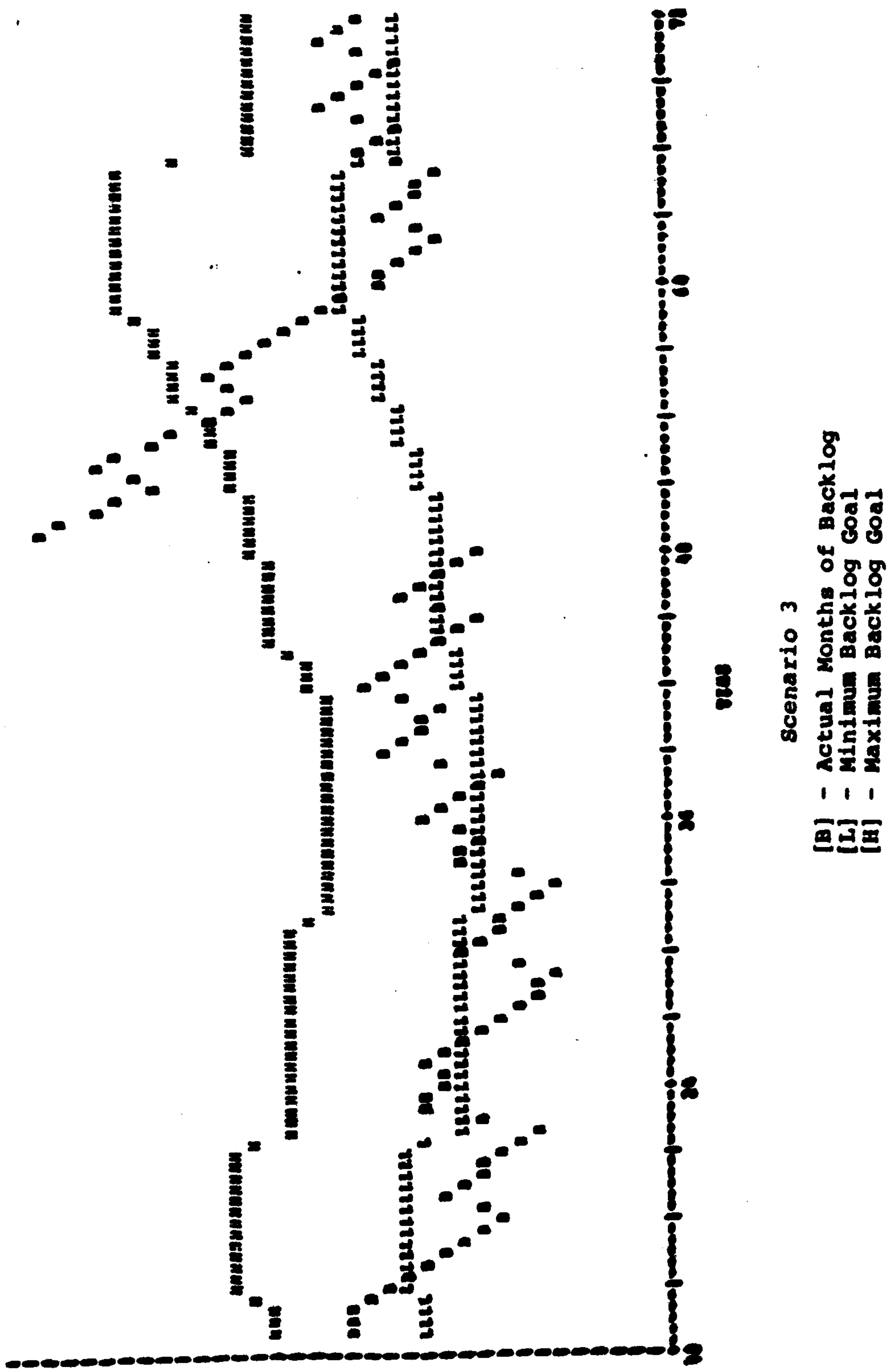
It snould be mentioned, in the "real world" this dilemma would most likely induce a plea for contract re-negotiation from the defense contractor. The mechanism by which contractual covenants may be modified has not been specified. Nevertheless, the purpose of generating Scenario 2 was to demonstrate the importance of a viable DOD monitor. Without the DOD presence in the operating environment, problems associated with project cost, quality and scheduling are clearly exasperated.

6.4 Scenario 3: Additional Major Project Awarded

The purpose of generating Scenario 3 is to investigate the effect a follow-on Major Project will have on project manager behavior and the operating environment in general. As mentioned previously, there is no mechanism currently specified in the DPM responsible for translating corporate IR&D allocations into new Major Projects. The awarding of a new Major Project can be simulated, however, by manually generating its occurrence--in this case--in period 49.

The reader is reminded that the DOD Sub-Model is once again fully operational. The only difference between Scenario 3 and the standard scenario is the awarding of a new contract in period 49.

Exhibit 6.23


Scenario 3
[B] - Actual Months of Backlog
[L] - Minimum Backlog Goal
[H] - Maximum Backlog Goal

6.4.1 Project Manager Considerations

Exhibit 6.23 demonstrates the most obvious difference between Scenario 3 and the standard scenario. The backlog increases drastically in period 49 and the minimum and maximum goals soon follow. While the buildup of backlog is worked down considerably by the end of the simulation, it is still higher than Scenario 1 (see Exhibit 6.1).

Beginning in period 49, the project manager loses all interest in generating new projects as shown in Exhibit 6.24. The proportion of the workforce on indirect activities and the associated level of newly-submitted proposals drops drastically between periods 49 and 60. In addition, the quality of indirect activities is extremely low during the period as demonstrated in Exhibit 6.25. As expected, the capture rate is also very low in periods 49-60.

The project manager is able to increase his labor force to a high level in Scenario 3 as shown in Exhibit 6.26. Because the size of the labor force has been quickly expanded in a relatively short period, the quality is somewhat lower than in the standard scenario (see Exhibits 6.27 and 6.6).

In general, the project manager behaved as expected upon receiving the new major project. Resources were transferred from new project generating activities to direct activities and the workforce was quickly expanded. This extreme behavior is not without its consequences, as will be discussed below.

Exnibit 6.24

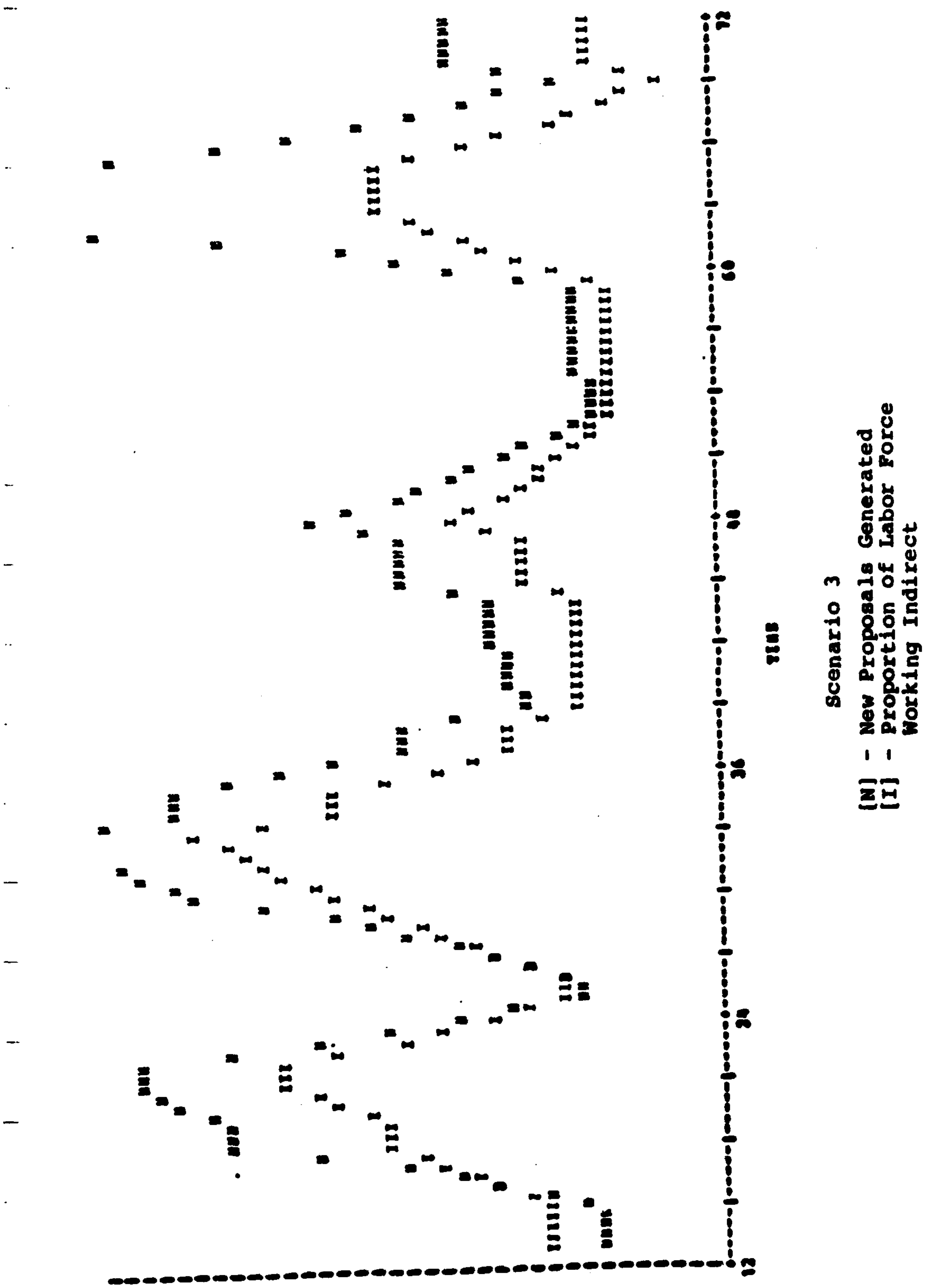

12
24
36
48
60
72
TIME
Scenario 3
[N] - New Proposals Generated
[I] - Proportion of Labor Force
Working Indirect

Exhibit 6.25

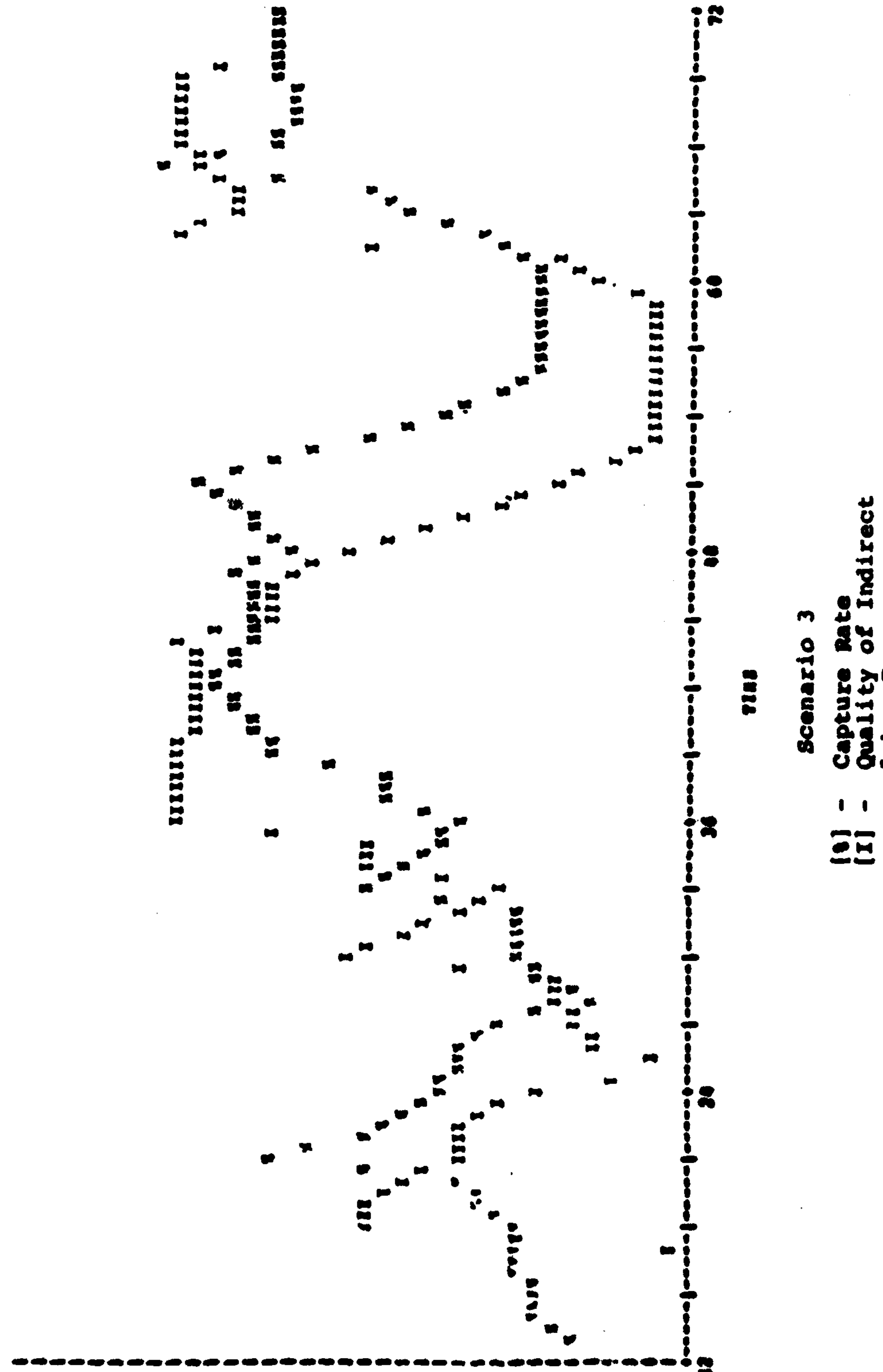
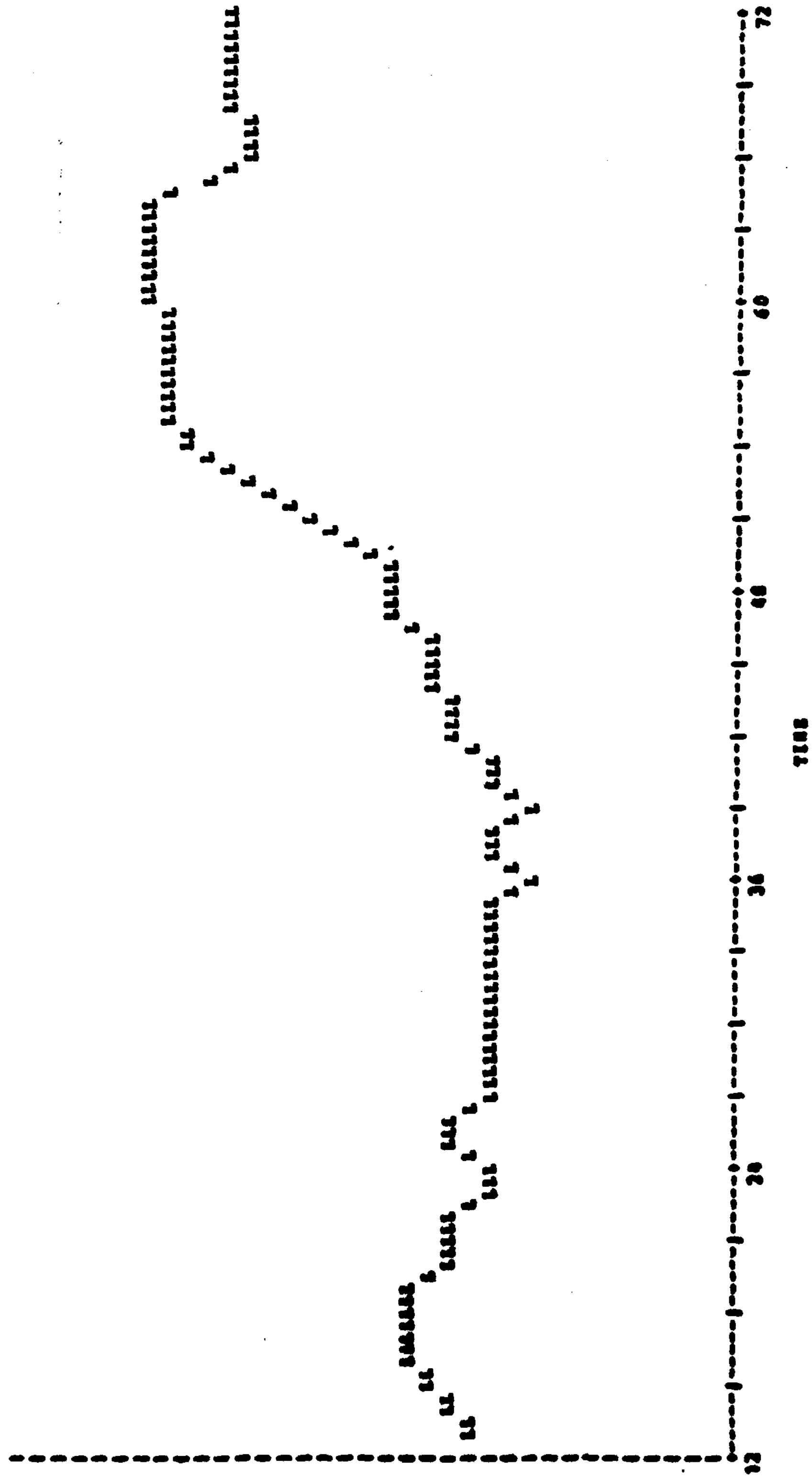

TIME
Scenario 3
[S] - Capture Rate
[I] - Quality of Indirect
Labor Force

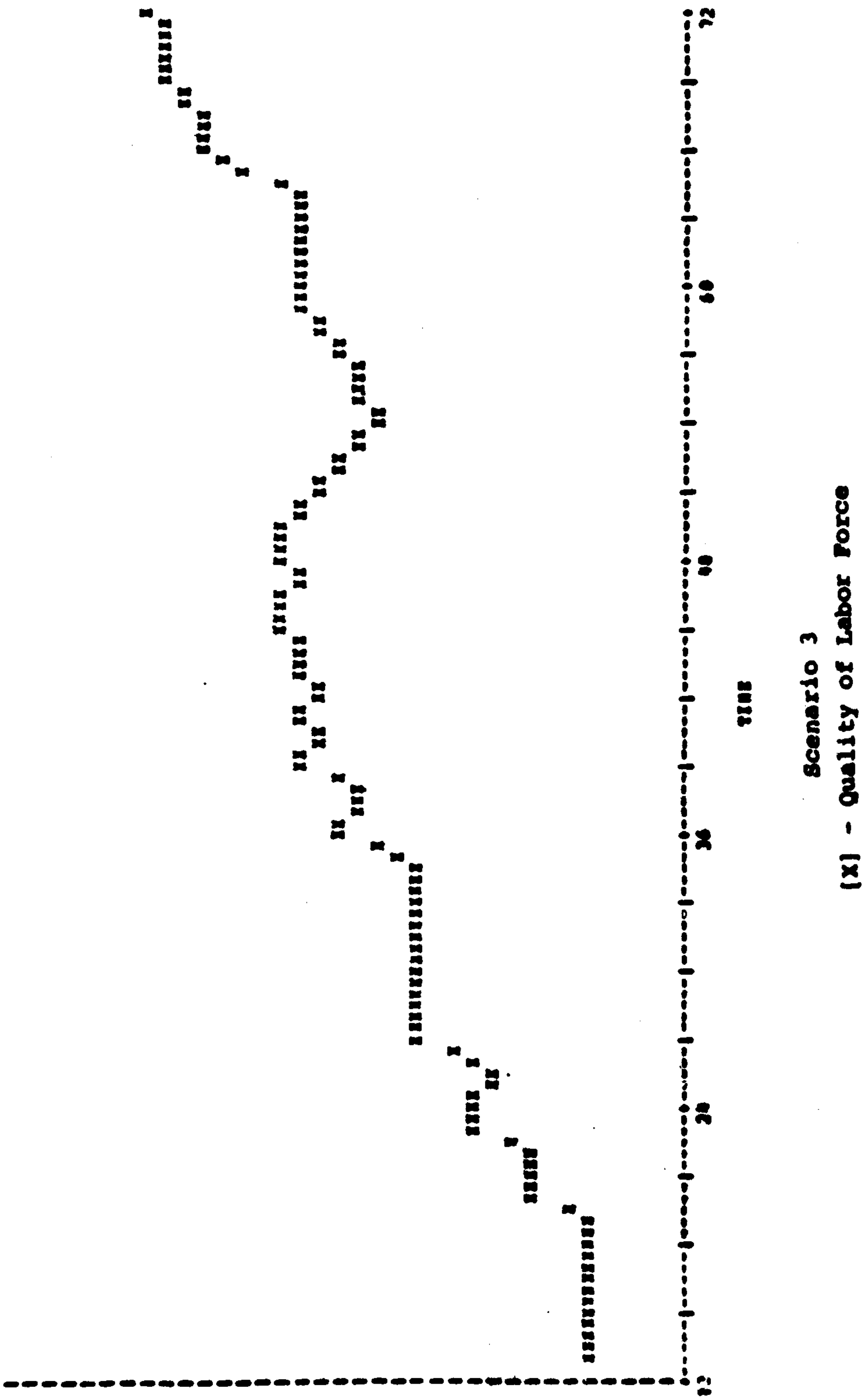
Exhibit 6.26



Scenario 3

[L] - Size of Labor Force

Exhibit 6.27



6.4.2 Corporate Considerations

Cash flow performance and Corporate Pressure are plotted in Exhibit 6.28. When compared with Scenario 1, the cash flow performance between periods 49 and 60 is much improved. However, there is an extended period beginning in period 61 where cash flows are negative. This is the result of the project manager ignoring proposal writing activities and being unable to support his new (higher) backlog goals with an expanded labor force. The actual backlog is below the minimum acceptable level (see Exhibit 6.23) beginning in period 58 and the project manager begins transferring personnel out of direct to proposal writing activities (see Exhibit 6.29). This decreases billable time and the cash flow performance suffers accordingly.

6.4.3 DOD Considerations

The project manager's performance on the first Major Project is, of course, identical to the standard scenario. However, there is an interesting (shortlived but favorable) occurrence with respect to the follow-on Major Project. As mentioned above, the project manager scaled-down the size and quality of his proposal writing activities upon receipt of the new Major Project. This resulted in very high quality personnel being available for assignments with the direct work force. As demonstrated in Exhibit 6.30, the quality of work performed on the Major Project voluntarily exceeded the DOD quality goal the

Exhibit 6.28

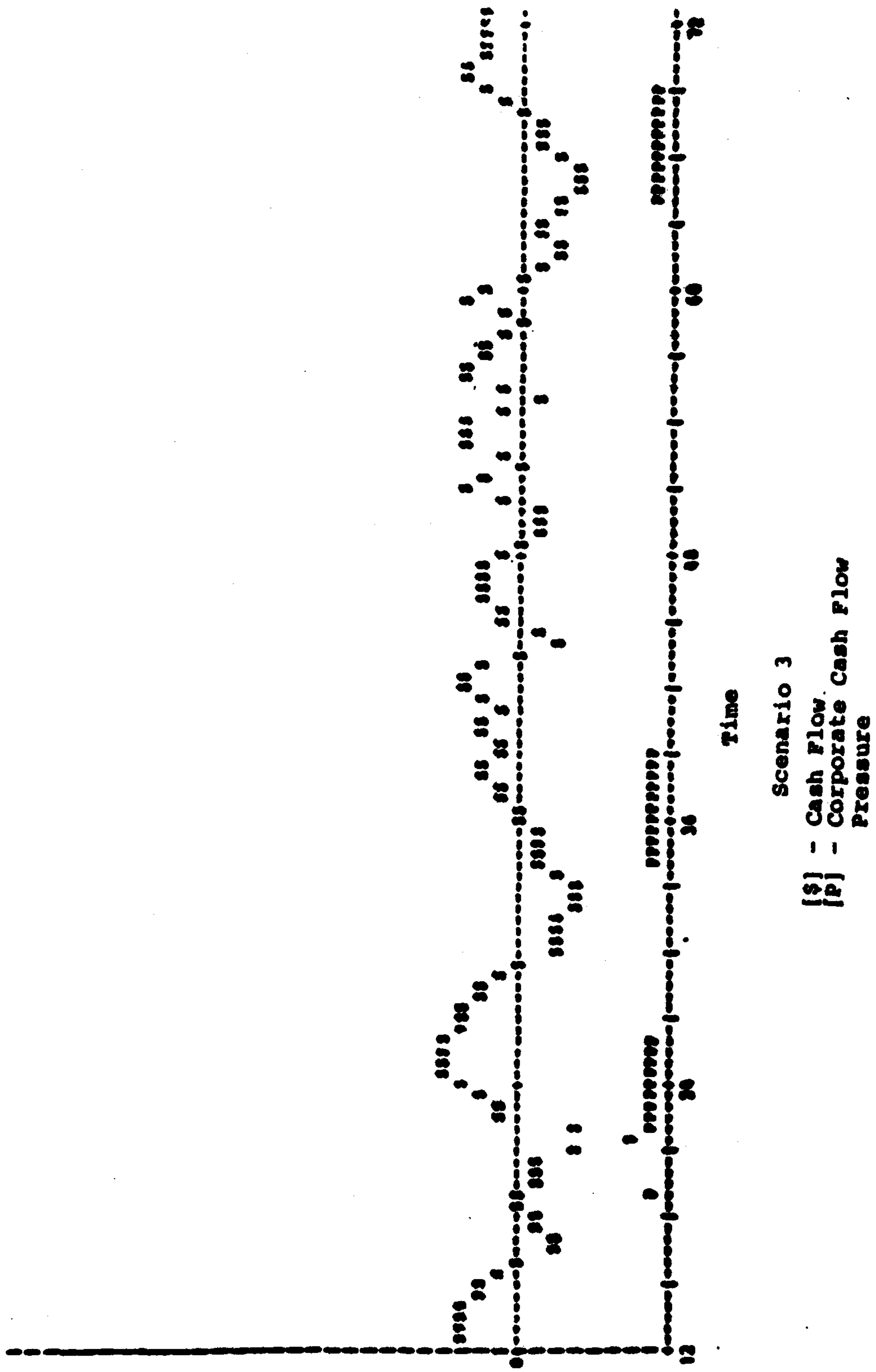
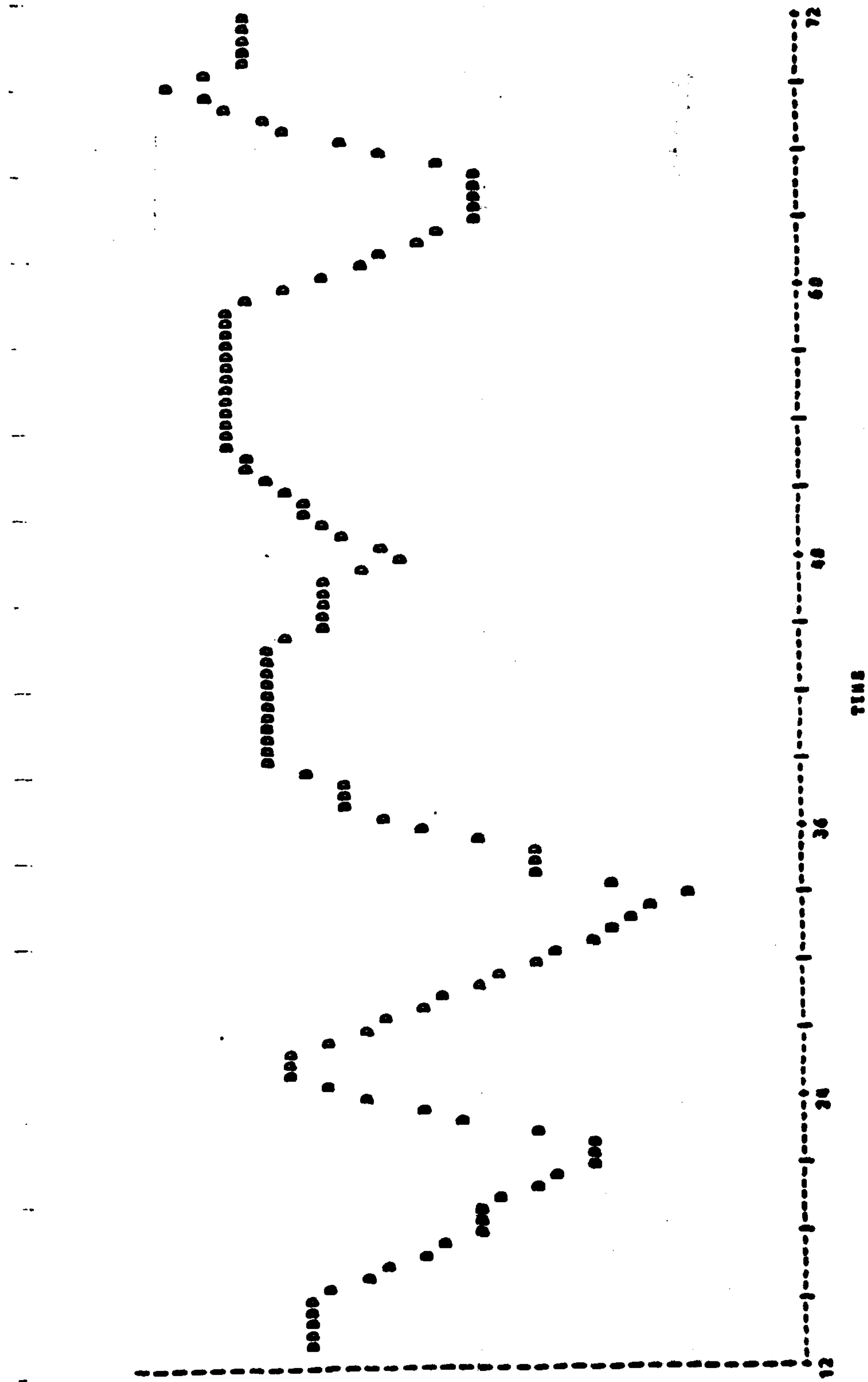


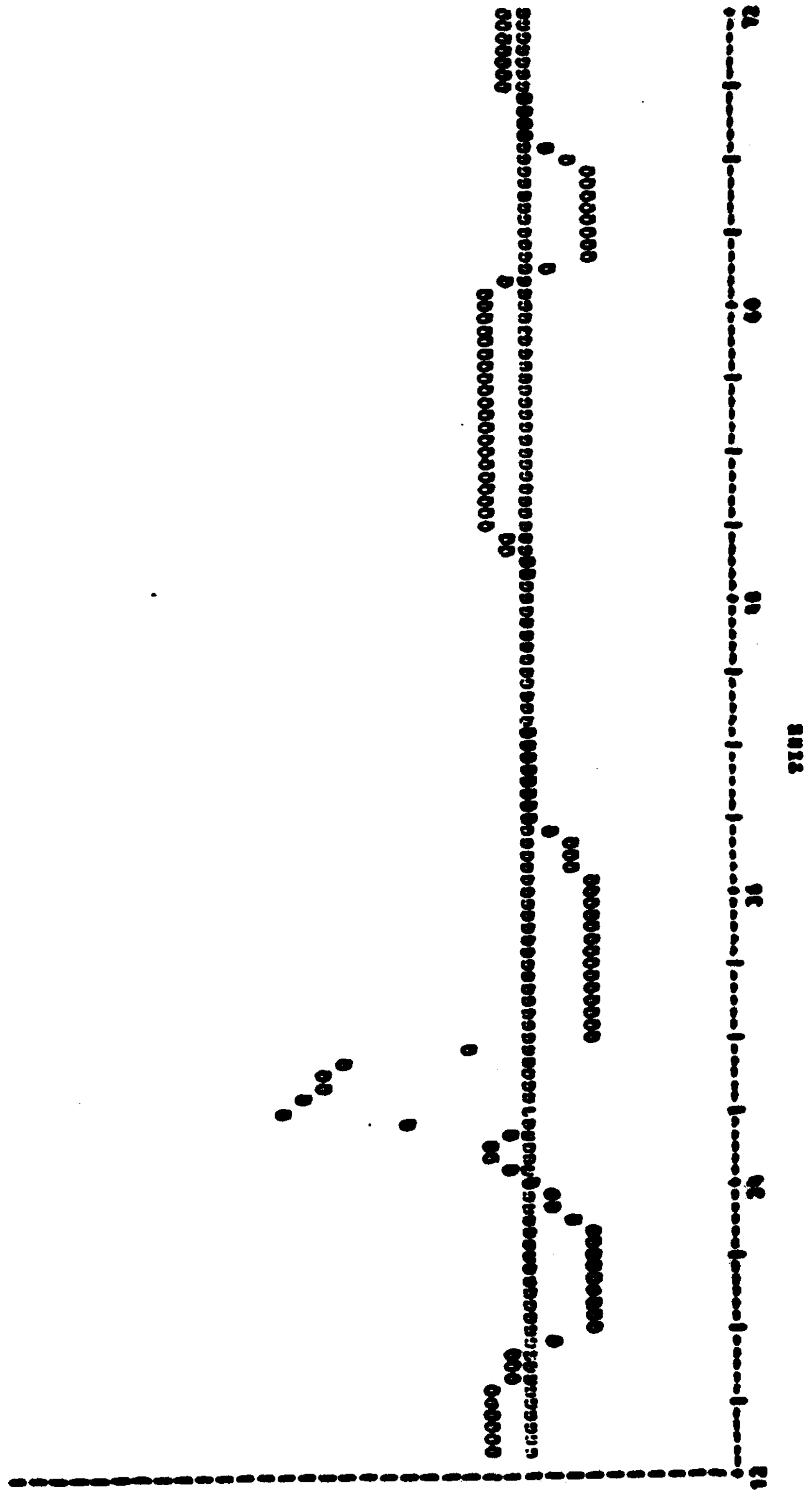
Exhibit 6.29



Scenario 3

[D] - Proportion of Labor Force Working Direct

Exhibit 6.30

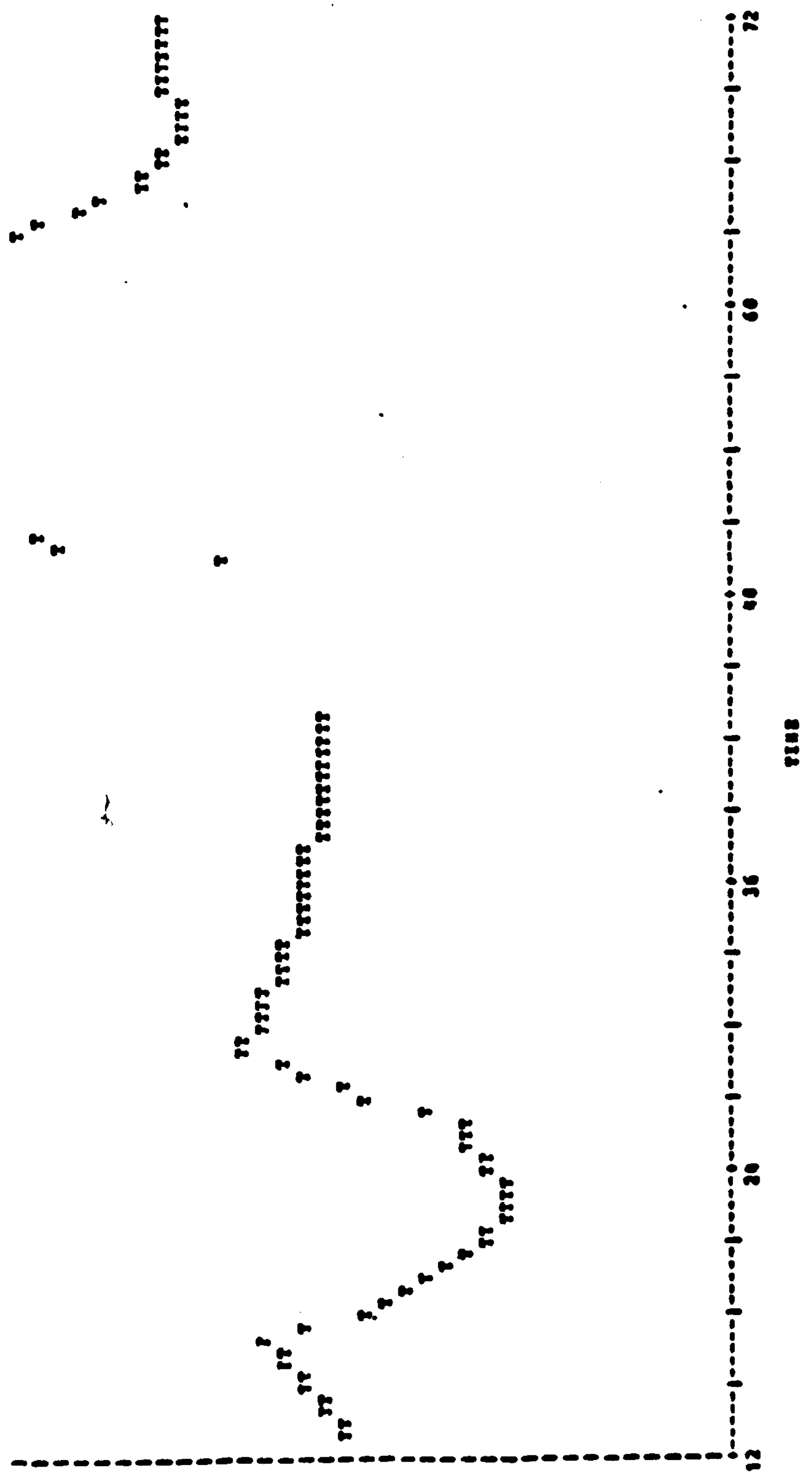


Scenario 3

[Q] - Current Quality Performance
[G] - Quality Goal

first year (12 periods) of the project. In fact, the cumulative quality leaves the vertical scale, as shown in Exhibit 6.31, until after period 62. Of course, any DOD Quality Pressure directed at the follow-on Major Project will be absent in Scenario 3.

Exhibit 6.31



Scenario 3
[T] - Overall Quality of Performance

6.5 Conclusion

Despite the progress made in creating a sophisticated and realistic operating environment for the DPM, additional research is necessary before the model can be considered a viable tool in the investigation of improved incentive schemes. The DPM's many behavioral parameters, underlying assumptions and structural composition must be tested and validated through use of several methodological approaches before policy recommendations may be formulated.

The initial step in the validation process is a general test of plausibility through examination of various scenarios generated by modification of model attributes. Several scenarios were generated and seemed to provide reasonable and consistent results. However, more testing of this sort will be required. For example, modification of the capture rate algorithm, awarding of "major" spinoff projects, absence of a corporate level DOD Quality Pressure mechanism and a smaller initial labor force would all be informative scenarios to analyze.

The next step in the validation process involves extensive statistical regression analysis of the behavioral parameters and initial conditions. A methodology similar to the approach developed by Cyert and March in the Behavioral Theory of the Firm is applicable for the DPM due to the number of variables involved and complexity of the model structure. A determination

of model attributes to which key performance variables are most sensitive is the objective of this statistical investigation. In conjunction with sensitivity analysis, field interviews and surveys of management in DOD contracting organizations will be necessary to insure DPM consistency with the "real world."

Finally, after necessary modifications to the DPM are implemented as determined in the validation process, the model will become a "testing-grounds" for the development and implementation of improved incentive mechanisms. Thorough validation of the DPM is necessarily required, however, before policy recommendations can be made with any degree of confidence.

APPENDIX I

```
I = 1
    IF STOP=1
GO TO ERROR1
        END
    IF STOP = 2
GO TO ERROR2
        END
    IF STOP = 3
GO TO ERROR3
        END
>**CORPORATE PRESSURE CHECK**<
    IF CFP = 1
    GO TO PRESSURE 50
        END
 > CORPORATE PRESSURE NOT APPLIED <
 >>* BACKLOG CHECK NO CORPORATE PRESSURE *<<
    IF BACKLOG < BACKMIN
 > BACKLOG GOAL IS LOW <
PI = PI(-1) + AI*(1-PI(-1))
PD = 1 - PI
LABORQTY = 0
    GO TO IQUALINC 50
        END
    IF BACKLOG > BACKMAX
 > BACKLOG GOAL IS HIGH <
PD = PD(-1) + AD*(1-PD(-1))
PI = 1 - PD
LABORQTY = 1
    GO TO DQUALINC 50
     ELSE
 > BACKLOG GOAL IS OK <
LABORQTY = 0
        END
 >>* VOLUME CHECK NO CORPORATE PRESSURE *<<
PD = PD(-1)
PI = PI(-1)
PHD=PHD(-1)+(PH-PH(-1))*(PHD(-1)/PH(-1))
PHI=PHI(-1)+(PH-PH(-1))*(PHI(-1)/PH(-1))
PLD=PLD(-1)+(PL-PL(-1))*(PLD(-1)/PL(-1))
PLI=PLI(-1)+(PL-PL(-1))*(PLI(-1)/PL(-1))
    IF VOLUME < VOLMIN
 > VOLUME GOAL IS LOW <
LABORQTY = 1
    GO TO ASSIGNMENT 50
     ELSE
 > VOLUME GOAL IS OK <
LABORQTY = 0
        END
    GO TO ASSIGNMENT 50
PRESSURE:
 > CORPORATE PRESSURE BEING APPLIED <
 >>* BACKLOG CHECK WITH CORPORATE PRESSURE *<<
    IF BACKLOG < BACKMIN
 > BACKLOG GOAL IS LOW <
```

```
275 LABORQTY = -1
280 PD = PD(-1)
285 PI = PI(-1)
290    GO TO IQUALINC 50
295       END
300    IF BACKLOG > BACKMAX
305  > BACKLOG GOAL HIGH <
310 PD = PD(-1) + (AD*2)*(1-PD(-1))
315 PI = 1 - PD
320 LABORQTY = 0
325    GO TO DQUALINC 50
330       END
335  > BACKLOG GOAL IS OK <
340  >
345  >>* VOLUME CHECK WITH CORPORATE PRESURE *<<
350 PD = PD(-1) + (AD*2)*(1-PD(-1))
355 PI = 1 - PD
360 PHD = PHD(-1)*(1+(PD-PD(-1))/PD(-1))
365    IF PHD>PH | PHD>PD
370 PHD = MINIMUM (PH,PD)
375       END
380 PLD = PD - PHD
385    IF PLD > PL
390 TEMP = PHD
395 PHD = TEMP + PLD - PL
400 PLD = PL
405       END
410 PHI = PH - PHD
415 PLI = PL - PLD
420    IF VOLUME < VOLMIN
425  > VOLUME GOAL LOW <
430 LABORQTY = 1
435    GO TO ASSIGNMENT 50
440     ELSE
445  > VOLUME GOAL OK <
450 LABORQTY = 0
455    GO TO ASSIGNMENT 50
460       END
465  >
470  >## IQUALITY INCREASE ROUTINE ##<
475 IQUALINC:
480    IF BACKLOG (-1)<BACKMIN(-1) & LIMIT(-1)=1
485 BHI=.20
490       END
495 PHI = PHI(-1) + BHI*(PH-PHI(-1))
500    IF BACKLOG(-2)<BACKMIN(-2) &  BACKLOG(-1)<BACKMIN(-1) & -
505    CQPRESS-=1
510 PHI=PI
515       END
520    IF PHI>PH | PHI>PI
525 PHI=MINIMUM (PH,PI)
530       END
535 PLI = PI - PHI
540    IF PLI > PL
545 TEMP = PHI
550 PHI = TEMP + PLI - PL
```

```
PLI = PL
      END
PHD = PH - PHI
PLD = PL - PLI
   GO TO ASSIGNMENT 50
 >## DQUALITY INCREASE ROUTINE ##<
DQUALINC:
PHD = PHD(-1) + BHD*(PH-PHD(-1))
   IF PHD>PH | PHD>PD
PHD = MINIMUM(PH,PD)
      END
PLD = PD - PHD
   IF PLD > PL
TEMP = PHD
PHD = TEMP + PLD - PL
PLD = PL
      END
PHI = PH - PHD
PLI = PL - PLD
   GO TO ASSIGNMENT 50
 >
 >## PROJECT MANPOWER ASSIGNMENT ROUTINE ##<
 >
ASSIGNMENT:
DLABOR = PD*LABOR
HDLABOR = PHD*LABOR
LDLABOR = PLD*LABOR
DSALRATE=((HSALRATE**HDLABOR)*(LSALRATE**LDLABOR))**(1/DLABOR)
DQUALITY = ((HQUAL**HDLABOR)*(LQUAL**LDLABOR))**(1/DLABOR)
ILABOR = PI * LABOR
HILABOR = PHI*LABOR
LILABOR = PLI*LABOR
ISALRATE=((HSALRATE**HILABOR)*(LSALRATE**LILABOR))**(1/ILABOR)
IQUALITY = ((HQUAL**HILABOR)*(LQUAL**LILABOR))**(1/ILABOR)
LABQUAL=((DQUALITY**DLABOR)*(IQUALITY**ILABOR))**(1/LABOR)
FILE = 0
   IF SQMMBAL(1)<1 & QTOTPROJ(-1,1)<QGOAL
SQMMBAL(1)=8
XCQPRESS=1
      END
   IF (XCQPRESS(-1)=1 | XCQPRESS(-2)=1) & QTOTPROJ(-1,1)>QGOAL
SQMMBAL(1)=0
      END
SPINCALC:
FILE = FILE + 1
   IF FILE = 11
   GO TO END1 50
      END
   IF DELIVERY(FILE) = 0
   GO TO SPINCALC 50
      END
TIMELEFT(FILE) = DELIVERY(FILE) - TIME
   IF TIMELEFT(FILE) <= 0
MMRATE(FILE) = SQMMBAL(FILE)
    ELSE
MMRATE(FILE) = SQMMBAL(FILE) / TIMELEFT(FILE)
```

```
          END
       IF FILE=1
GO TO SPINCALC 50
          END
TSPINSQMM(1) = TSPINSQMM(1) + SQMMBAL(FILE)
TMMRATE(1) = TMMRATE(1) + MMRATE(FILE)
   GO TO SPINCALC 50
END1:
FILE=1
   IF SCHPRESS=1
KPM=1.20
      END
MAJWT=KPM*MMRATE(1)/(MMRATE(1)+TMMRATE(1))
MODWT:
   IF MAJWT-=0 &  ((PMQPRESS=1 & CFP=0 & BACKLOG>BACKMIN) | -
 ((CQPRESS=1 & CFP=0)) |  XCQPRESS=1)
SDQUAL=.8
MDQUAL=(DQUALITY/(SDQUAL**(1-MAJWT)))**(1/MAJWT)
   IF MDQUAL>1.25
MDQUAL=1.25
MAJWT=MMRATE(1)/(DLABOR*MDQUAL)
SDQUAL=(DQUALITY/(MDQUAL**MAJWT))**(1/(1-MAJWT))
   IF SDQUAL<.8
  GO TO ERROR1
      END
      END
      ELSE
SDQUAL=DQUALITY
MDQUAL=DQUALITY
      END
   IF ((1-MAJWT)*DLABOR*SDQUAL)>TSPINSQMM(1)
  IF MAJWT=0
GO TO ERROR1
      END
  IF (MAJWT*DLABOR*MDQUAL)>SQMMBAL(1)
   GO TO ERROR1
      END
  IF MDQUAL=1.25
 GO TO ERROR1
     END
MAJWT = 1-(TSPINSQMM/(DLABOR*SDQUAL))
   GO TO MODWT 1
 GO TO ERROR1
      END
   IF (MAJWT*DLABOR*MDQUAL)>SQMMBAL
MAJWT = SQMMBAL/(DLABOR*MDQUAL)
   IF ((1-MAJWT)*DLABOR*SDQUAL)>TSPINSQMM(1)
GO TO ERROR1
      END
   GO TO MODWT 1
 GO TO ERROR1
      END
PRIORITY(1) = KDOD*MAJWT
SPINWT(1) = 1 - MAJWT
SQMMWORKED(1)=PRIORITY*DLABOR*MDQUAL
SQMMBAL(+1,1) = SQMMBAL - SQMMWORKED
```

```
   IF SQMMBAL(+1)<1
SQMMBAL(+1)=0
      END
   IF SQMMBAL(+1,1)=0 & MAJWT-=0
COMPLETED(1) = 1
END
    IF SQMMBAL(+1,1) < 0
GO TO ERROR3
     END
SPINALLOC:
FILE = FILE + 1
    IF FILE = 11
    GO TO END2 50
       END
    IF DELIVERY(FILE) = 0
    GO TO SPINALLOC 50
       END
   IF TMMRATE = 0
PRIORITY(FILE) = 0
GO TO SPINALLOC 50
      END
PRIORITY(FILE)=SPINWT(1)*MMRATE(FILE)/TMMRATE
SQMMWORKED(FILE)=PRIORITY(FILE)*DLABOR*SDQUAL
SQMMBAL(+I,FILE) = SQMMBAL(FILE)-SQMMWORKED(FILE)
IF SQMMBAL (+I,FILE) < 1
COMPLETED(FILE)=1
   SQMMBAL(+I,FILE) = 0
    ELSE
DELIVERY(FILE,+I) = DELIVERY(FILE)
TPPOJSQMM(FILE,+I) = TPROJSQMM(FILE)
      END
    IF COMPLETED(-1,FILE)=1
COMPLETED(FILE)=0
      END
    IF DELIVERY(FILE) <= TIME
    IF SQMMBAL(+I,FILE) > 0
DELIVERY(+I,FILE) = DELIVERY(FILE)
TPPOJSQMM(FILE,+I)=TPPOJSQMM(FILE)
      END
      END
   GO TO SPINALLOC 50
END2:
FILE = 1
  >
  >## PROJECT UPDATE ROUTINE ##<
  >
DOLLARS:
   IF FILE = 11
   GO TO END3 50
      END
   IF DELIVERY(FILE) = 0
FILE = FILE+1
   GO TO DOLLARS 50
      END
   IF FILE=1
```

```
CURR$PROJ(FILE)=DLABOR*DSALRATE*PRIORITY(FILE)* -
(MDQUAL/DQUALITY)*(1+NEGOH)
      ELSE
CURR$PROJ(FILE)=DLABOR*DSALRATE*PRIORITY(FILE)* -
(SDQUAL/DQUALITY)*(1+NEGOH)
      END
TOT$BILLED(FILE)=TOT$BILLED(FILE,-1)+CURR$PROJ(FILE)
FILE = FILE + 1
   GO TO DOLLARS 50
END3:
FILE = 1
   IF CQPRESS=1 & BACKLOG>BACKMIN & LIMIT¬=1
TSPINSQMM(1)=0
TMMRATE(1)=0
   IF LIMIT(-3)=1 & LIMIT(-2)=1 & LIMIT(-1)=1
BHD=BHD*2
      END
   IF LIMIT(-2)=1 & LIMIT(-1)=1
BHD=BHD*1.75
      END
   IF LIMIT(-1)=1
BHD=BHD*1.5
      END
   IF LIMIT(-1)¬=1
BHD=BHD*1.25
      END
LIMIT=1
   GO TO DQUALINC 1
END
QUALITY:
   IF FILE = 11
   GO TO END4 50
      END
   IF DELIVERY(FILE) = 0
FILE = FILE+1
   GO TO QUALITY 50
      END
   IF FILE=1
QCURRPROJ(FILE)=MDQUAL
   ELSE
QCURRPROJ(FILE)=SDQUAL
      END
QTOTPROJ(FILE)=(QTOTPROJ(FILE,-1)**(TPROJSQMM(FILE)-  -
SQMMBAL(FILE))*QCURRPROJ(FILE)**SQMMWORKED(FILE))**
(1/(TPROJSQMM(FILE)-SQMMBAL(FILE)+SQMMWORKED(FILE)))
FILE = FILE + 1
   GO TO QUALITY 50
END4:
FILE = 1
  >
  >## CAPTURE RATE DETERMINATION ROUTINE ##<
  >
AVEQUAL=DQUALITY(-12)**(1/9)*DQUALITY(-11)**(1/9)* -
    DQUALITY(-10)**(1/9)*DQUALITY(-9)**(1/9)*DQUALITY(-8)**(1/9)* -
    DQUALITY(-7)**(1/9)*DQUALITY(-6)**(1/9)*DQUALITY(-5)**(1/9)* -
    DQUALITY(-4)**(1/9)
VAEQUAL = ((DQUALITY(-12)-AVEQUAL)**2+(DQUALITY(-11)-AVEQUAL)**2+ -
```

```
     (DQUALITY(-10)-AVEQUAL)**2+(DQUALITY(-9)-AVEQUAL)**2+ -
     (DQUALITY(-8)-AVEQUAL)**2+(DQUALITY(-7)-AVEQUAL)**2+ -
     (DQUALITY(-6)-AVEQUAL)**2+(DQUALITY(-5)-AVEQUAL)**2+ -
     (DQUALITY(-4)-AVEQUAL)**2)
QPERFORM = BETA*(AVEQUAL**B1)*(VARQUAL**B2)
DUMMY = -(GAMMA+G1*IQUALITY(-3)+G2*QPERFORM)
CAPTRATE = 1/(1+EXP(DUMMY))
NEWPRPSLS = ILABOR*IQUALITY*PRPMULT*(HSALRATE*PH+LSALRATE*PL))
NEWCONTR = CAPTRATE*NEWPRPSLS(-3)
OUTCONTR = OUTCONTR(-1)+NEWCONTR
   IF OUTCONTR > AWARD
   GO TO PROJECTADD 50
    ELSE
   GO TO END5 50
      END
END5:
FILE = 1
  >
  >## MANPOWER ADJUSTMENT ROUTINE ##<
    IF LABORQTY = 1
LABOR(+1) = (1+GROWTH)*LABOR
      END
   IF LABORQTY = -1
LABOR(+1) = (1-GROWTH)*LABOR
      END
   IF LABORQTY = 0
LABOR(+1) = LABOR
      END
  >>ATTRITION SUB-MODEL<<
   IF LABORQTY=-1 & LABORQTY(-1)=-1
HLABOR=.98*(HDLABOR+HILABOR)
LLABOR=LDLABOR+LILABOR
    ELSE
HLABOR=HDLABOR+HILABOR
LLABOR=LDLABOR+LILABOR
      END
   IF LABORQTY -= -1
   GO TO HIRING
      END
 >>FIRING SUB-MODEL<<
HLABOR(+1)=HLABOR
LLABOR(+1)=LABOR(+1)-HLABOR(+1)
   GO TO BRKDOWN
HIRING:
   IF LABORQTY -= 1
   GO TO STATUSQUO
      END
 >>HIRING SUB-MODEL<<
HLABOR(+1)=1.02*HLABOR
LLABOR(+1)=LABOR(+1)-HLABOR(+1)
   GO TO BRKDOWN
STATUSQUO:
 >>STATUS-QUO SUB-MODEL<<
   IF LABORQTY=-1    BACKLOG<BACKMIN
HLABOR(+1)=HLABOR
LLABOR(+1)=LABOR(+1)-HLABOR(+1)
```

```
   GO TO BRKDOWN
     END
HLABOR(+1)=I.01*HLABOR
LLABOR(+1)=LLABOR
LABOR(+1)=HLABOR(+1)+LLABOR(+1)
   GO TO BRKDOWN
BRKDOWN:
PH(+1)=HLABOR(+1)/LABOR(+1)
PL(+1)=LLABOR(+1)/LABOR(+1)
VOLUME(+1) = LABOR(+1)
FILE = 1
 >
 >>## BACKLOG CALCULATION SUB-MODEL ##<<
 >
BACK$:
   IF FILE=11
   GO TO END6 50
      END
   IF DELIVERY(FILE)=0
FILE=FILE+1
   GO TO BACK$ 50
      END
REMPROJ$(FILE) = REMPROJ$(FILE,-I) - CURR$PROJ(FILE)
   IF REMPROJ$(FILE,-I) = 0
OVERCOST = CURR$PROJ(FILE)
REMPROJ*(FILE) = 0
      END
   IF REMPROJ$(FILE) < 0
OVERCOST = -(REMPROJ$(FILE))
REMPROJ$(FILE) = 0
      END
   IF REMPROJ$(FILE)=0 & REMPROJ$(FILE,+I)>0
REMPROJ$(FILE) = REMPROJ$(FILE,+I)
      END
TOT$BACK=TOT$BACK+REMPROJ$(FILE)
FILE=FILE+1
   GO TO BACK$ 50
END6:
FILE=1
BACKLOG(+1)=TOT$BACK/((PH(+1)*LABOR(+1)*HSALRATE) -
   +(PL(+1)*LABOR(+1)*LSALRATE))
 >
 >## CASH FLOW CALCULATION ROUTINE ##<
 >
FEE=.10*DLABOR*DSALRATE*(1+NEGOH)
ADMIN=PERCNTAD*DLABOR*DSALRATE
CORPIRD=.135*DLABOR*DSALRATE
   IF TCASHFLOW(-1) < 0
STLOAN=TCASHFLOW(-1)
STINVES=0
     ELSE
STINVEST=TCASHFLOW(-1)
STLOAN=0
      END
OUTCASH=FIXCORP+ADMIN+CORPIRD+DLABOR*DSALRATE+ILABOR*ISALRATE+ -
     (INTEREST+.03)*STLOAN/12
```

```
INCASH=DLABOR*DSALRATE*(1+NEGOH)+INTEREST*STINVEST/12+ -
    .8*FEE/12 - OVERCOST
CASHFLOW=INCASH-OUTCASH
TCASHFLOW=TCASHFLOW(-1)+CASHFLOW
   IF MOD(TIME,12)=1
YCASHFLOW=CASHFLOW
   ELSE
YCASHFLOW=YCASHFLOW(-1)+CASHFLOW
      END
 >
 >## GOAL ADJUSTMENT ROUTINE ##<
 >
   IF MOD(TIME,3)=0
   IF CASHFLOW(-2)+CASHFLOW(-1)+CASHFLOW<FLOWMIN
CFP(+1)=1
FLOWMIN(+3)=FLOWMIN
PERCNTAD(+1)=PERCNTAD-.05*(1-PERCNTAD)
   ELSE
CFP(+1) = 0
PERCNTAD(+1)=PERCNTAD+.05*(1-PERCNTAD)
      END
   ELSE
IF (CASHFLOW(-5)+CASHFLOW(-4)+CASHFLOW(-3)+CASHFLOW(-2)   -
  +CASHFLOW(-1)+CASHFLOW)>0
CFP(+1)=0
   ELSE
CFP(+1)=CFP
      END
PERCNTAD(+1)=PERCNTAD
      END
   IF CFP=0 & BACKLOG>BACKMIN & CFP(-1)=0 -
  & BACKLOG(-1)>BACKMIN(-1) & BACKMIN=BACKMIN(-1)
BACKMAX(+1)=BACKMAX*1.05
BACKMIN(+1)=BACKMIN*1.05
   ELSE
BACKMAX(+1)=BACKMAX
BACKMIN(+1)=BACKMIN
      END
   IF BACKLOG(-5)<BACKMIN(-5) & BACKLOG(-4)<BACKMIN(-4) & -
     BACKLOG(-3)<BACKMIN(-3) & BACKLOG(-2)<BACKMIN(-2) & -
    BACKLOG(-1)<BACKMIN(-1) & BACKLOG<BACKMIN & BACKMIN=BACKMIN(-1) & -
    BACKMIN=BACKMIN(-2) & BACKMIN=BACKMIN(-3) & -
    BACKMIN=BACKMIN(-4) & BACKMIN=BACKMIN(-5)
BACKMIN(+1)=BACKLOG+(BACKMIN-BACKLOG)/2
    IF BACKMIN(+1)<6
BACKMIN(+1)=6
      END
BACKMAX(+1) = BACKMIN(+1) + 6
      END
   IF LABORQTY=1 & BACKLOG(+1)<BACKMIN(+1)
HLABOR(+1)=1.01*HLABOR
LLABOR(+1)=LLABOR
LABOR(+1)=HLABOR(+1)+LLABOR(+1)
LABORQTY=0
PH(+1)=HLABOR(+1)/LABOR(+1)
PL(+1)=LLABOR(+1)/LABOR(+1)
```

```
VOLUME(+1) = LABOR(+1)
   GO TO END6 50
      END
     IF LABORQTY=-1
VOLMIN(+1)=.99*VOLMIN
   ELSE
    IF CFP=0 & BACKLOG(+1)>BACKMIN(+1)
VOLMIN(+1)=1.01*VOLMIN
   ELSE
VOLMIN(+1)=VOLMIN
      END
      END
 >## DOD SUB-MODEL ##<
> SCHEDULE CHECK <
   IF TIMELEFT <= 0 & SQMMBAL(+1)>0
SCHPRESS(+1)=1
   ELSE
SCHPRESS(+1)=0
      END
> QUALITY CHECK <
   IF QTOTPROJ(-1)<QGOAL
PMQPRESS(+1)=0
      END
   IF PMQPRESS(+1)=1 & PMQPRESS=1 & PMQPRESS(-1)=1
CQPRESS(+1)=0
      END
> END OF ITERATION <
   GO TO EXIT
 >
 >## SPINOFF PROJECT AWARD ROUTINE ##<
 >
PROJECTADD:
FILE=1
FINDFILE:
   IF FILE=11
   GO TO END5 50
      END
IF DELIVERY(FILE) = 0
GO TO NEWPROJ 50
ELSE
FILE=FILE+1
   GO TO FINDFILE 50
      END
NEWPROJ:
PROJECT(6) = FILE
QTOTPROJ(FILE)=1
TPPCJSQMM(FILE)=OUTCONTR/(PH*HQUAL*HSALRATE*(1+NEGOH) -
      PL*LQUAL*LSALRATE*(1+NEGOH)*1.10)
PROJECT(1) = TPROJSQMM(FILE)
DUMMY2 = EXP(-(.01*NEWCONTR))
DUMMY3=1/(1+DUMMY2)
DUMMY4=3+15*DUMMY3
TERM=POUND(DUMMY4,0)
DUE=TIM_+TERM
PROJECT(3) = DUE
DELIVERY(FILE) = DUE
```

```
MONTHS=0
SETDLVRY:
   IF MONTHS=TERM
   GO TO DLVRYSET 50
    ELSE
MONTHS=MONTHS+1
      END
DELIVERY(FILE,+MONTHS)=DUE
TPROJSQMM(FILE,+MONTHS)=TPROJSQMM(FILE)
   GO TO SETDLVRY 50
DLVRYSET:
MONTHS=0
SETSIZE:
MONTHS=MONTHS+1
PEMPROJ$(FILE,+I) = OUTCONTR
PROJECT(2) = OUTCONTR
SQMMBAL(FILE,+I)=TPROJSQMM(FILE)
OUTCONTR = 0
   GO TO END5 50
ERROR1:
STOP(+1) = 1
GO TO EXIT
ERROR2:
STOP(+1) = 2
GO TO EXIT
ERROR3:
STOP(+1) = 3
GO TO EXIT
EXIT:
```

APPENDIX II.

ENDOGENOUS AND DUMMY VARIABLE LISTING*

CFP - dummy variable signifying corporate cash flow pressure where 1 represents pressure being applied in the current period [0].**

PI - proportion of workforce on indirect activities [.20].

PD - proportion of workforce on direct activities [.80].

LABORQTY - dummy variable signifying hiring (+1), firing (-1) or status-quo (0) decisions of the project manager [0].

PHD - proportion of total workforce considered high quality working direct [.20].

PHI - proportion of total workforce considered high quality working indirect [.05].

PLD - proportion of total workforce considered high quality working direct [.60].

PLI - proportion of total workforce considered high quality working indirect [.15].

DLABOR - number of workers on direct activities [80].

HDLABOR - number of high quality workers on direct [20].

LDLABOR - number of low quality workers on direct [60].

DSALRATE - average (geometric) salary rate of direct workforce [2.6864].

DQUALITY - quality index of direct workforce [.8843].

ILABOR - quality index of indirect workforce [20].

HILABOR - quality index of indirect workforce [5].

LILABOR - quality index of indirect workforce [15].

ISALRATE - quality index of indirect workforce [2.6864].

IQUALITY - quality index of indirect workforce [.89].

LABQUAL - average (geometric) quality index of overall workforce.

SQMMBAL(n) - standard quality of man-months of work remaining on the n^{th} project.

XCQPRESS - dummy variable signifying corporate level quality pressure on a completed project [0].

* in order of appearance in DPM (see Appendix I).

** initial values follow variable definations in brackets, where appliable.

TIMELEFT(n) - number of months remaining before the n^{th} project is contractually due to be completed.

MMRATE(n) - calculate rate at which work must be performed in order to meet delivery date.

TSPINSQMM - total man-months of incomplete work remaining on all Spinoff Projects [0].

TMMRATE - calculated rate at which work must be performed in order to complete all projects by their respective delivery dates.

MAJWT - priority weight for Major Project with respect to assignment of direct workforce [1].

SDQUAL - quality index of work currently performed on Spinoff Projects.

MDQUAL - quality index of work currently performed on Major Project.

SPINWT - priority weight for all Spinoff Projects with respect to assignment of direct workforce.

PRIORITY(n) - priority weight assigned to n^{th} Spinoff Project.

SQMMWORKED(n) - the amount of work, in SQMM's, performed on the n^{th} project in the current period.

SQMMBAL(n) - amount of work, in SQMM's, remaining to be performed on the n^{th} project at the end of the current period.

COMPLETED(n) - dummy variable signifying when work has been completed (1) on the n^{th} project [0].

DELIVERY(n) - delivery date contractually scheduled for the n^{th} project.

TPROJSQMM(n) - size of the n^{th} project in SQMM's.

CURR$PROJ(n) - amount of billings against the n^{th} project in the current period.

TOT$BILLED(n) - total billings against the n^{th} project at the end of the current period.

QCURRPROJ(n) - quality index of work performed on the n^{th} project in the current period.

QTOTPROJ(n) - cummulative quality index of work performed on the n^{th} project including the current period.

AVEQUAL - average (geometric) quality index of direct work performed the previous 12 periods.

VARQUAL - various of the quality index of work performed the previous 12 periods [.0012].

OPERFORM - overall quality of performance of previous direct work.

CAPTRATE - capture rate of proposals submitted the current period.

NEWPRPSLS - dollar volume of new proposals submitted to the DOD in the current period [500].

NEWCONTR - dollar volume of contracts awarded which accure to the current period.

OUTCONTR - cummulative dollar volume of accrued awarded contracts [0].

LABOR - total size of the current workforce [100].

HLABOR - number of workers considered high quality in current workforce [25].

LLABOR - number of workers considered low quality in current workforce [75].

PH - proportion of total workforce considered high quality [.25].

PL - proportion of total workforce considered low quality [.75].

REMPROJ$(n) - total dollars remaining in the n^{th} project budget.

OVERCOST(n) - cost overrun on the n^{th} project.

TOT$BACK - cummulative dollars remaining in all project budgets.

FEE - pro rated monthly billing against the contracted fixed-fee.

BACKLOG - number of months of fully burdened payroll in the project budget inventory [15].

ADMIN - monthly administration expenses.

CORPIRD - monthly allocation levied on project manager by corporate in support of IR&D.

STLOAN - current short-term borrowings of project manager from previous period [0].

STINVEST - current short-term investments of project manager from previous periods [0].

OUTCASH - total current cash outflow of project manager.

INCASH - total current cash inflow of project manager.

CASHFLOW - net current cash flow of project manager's organization.

TCASHFLOW - cummulative cash flow of project manager's organization.

YCASHFLOW - annual cash flow of project manager's organization.

FLOWMIN - minimum cash flow aspiration - level goal of corporate concerning project manager's organization [0].

PERCNTAD - current administrative expenses represented as a percent of total direct payroll [.05].

BACKMAX - project manager's current maximum backlog goal [18].

BACKMIN - project manager's current minimum backlog goal [12].

VOLMIN - project manager's minimum volume goal [100].

SCHPRESS - dummy variable signifying schedule pressure being applied on the project manager (1) by the DOD [0].

PMQPRESS - dummy variable signifying quality pressume being applied on the project manager (1) by the DOD [0].

LQPRESS - dummy variable signifying corporate level quality pressure being relayed to the project manager from the DOD [0].

TERM - duration in months of a newly awarded Spinoff Project.

DELIVERY(n) - delivery date of the n^{th} project.